Power Outage Report

1. Date / Weather : , , 2021 /
2. Office :
   Province / District : /
3. Substation / Feeder : /
4. Power failure detection : □OC □EF □OC･EF
5. Outage duration(Maximum) : minutes
6. Number of customer (Maximum) : customers
7. Progress of Restore

	Time	Number of Restored Customer.	Remarks
Power outage		—	
Partial recovery1			
Partial recovery2			
Partial recovery3			
Partial recovery4			
Partial recovery5			
Partial recovery6			
Full recovery			

8. Category of power outage(A01~28) : A
   Detail (If A28) :
9. Damaged Part :
10. Failure Cause in detail

(photo and figure of local site / damaged part)

11. Location of failure cause. (indicate into SLD)

Example

Power Outage Report (The Firstt Draft to Discuss)

1. Date / Weather : 5th, July, 2021 / Rainy

2. Office : XXXXX
   Province / District : NCP / Anuradhapura

3. Substation / Feeder : Habarana / 07

4. Power failure detection : ☑OC ☐EF ☐OC·EF

5. Outage duration(Maximum) : 180 minutes

6. Number of customer (Maximum) : 4,567 customers

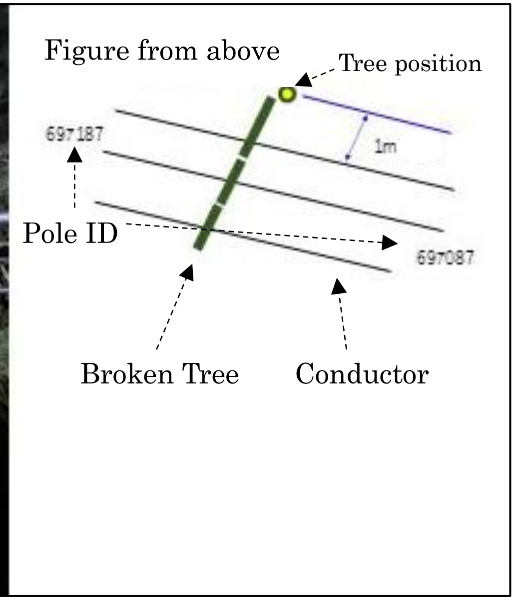
7. Progress of Restore

	Time	Number of Restored Customer.	Remarks
Power outage	16:30	—	
Partial recovery1	17:00	1,567	
Partial recovery2	17:30	1,400	
Partial recovery3	17:45	1,200	
Partial recovery4	18:00	300	
Partial recovery5	—	—	
Partial recovery6	—	—	
Full recovery	19:30	100	

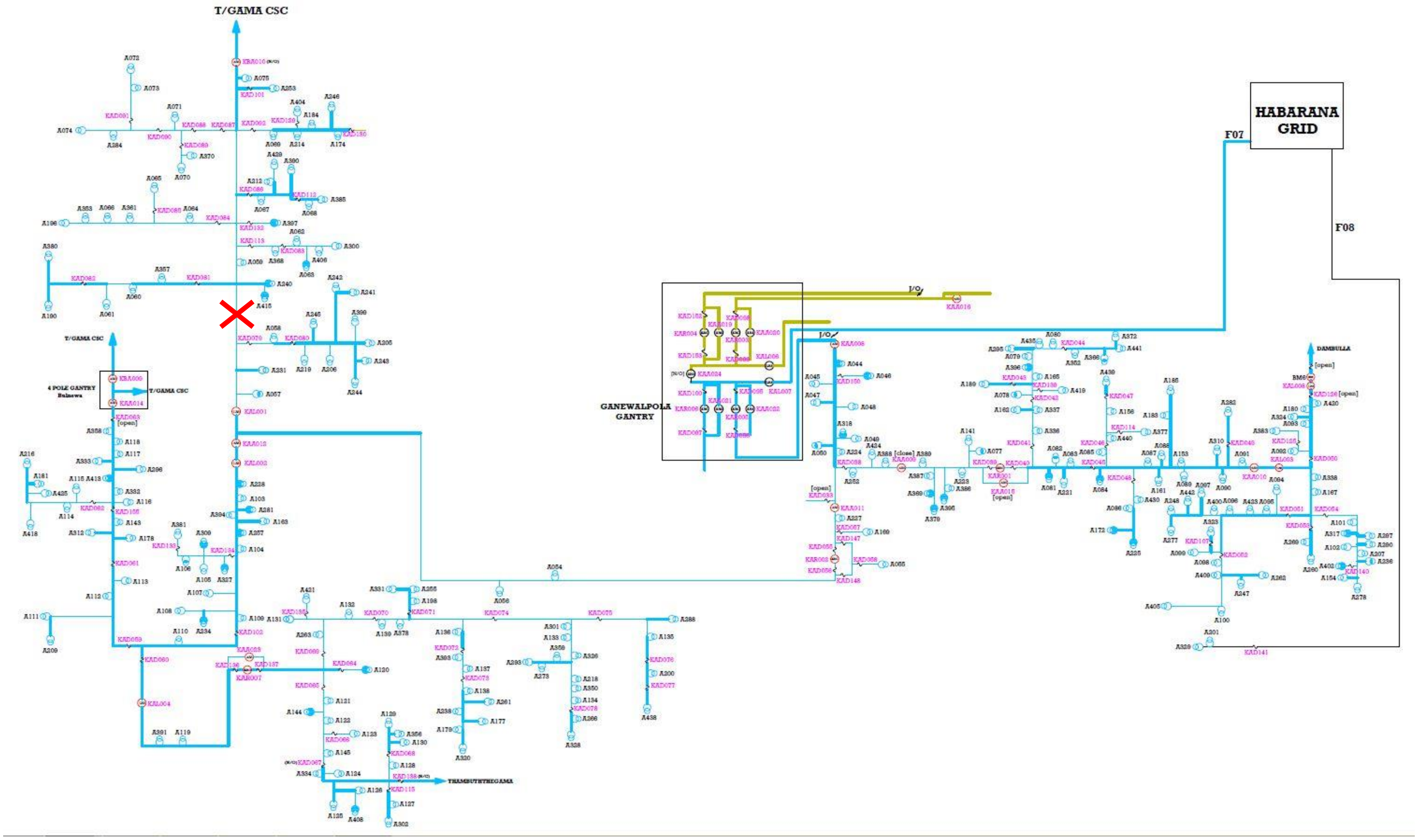
8. Category of power outage(A01~28) : A09
   Detail (If A28) :

9. Damaged Part : conductor

10. Failure Cause in detail
    A broken tree touched conductors.



11. Location of failure cause. (indicate into SLD)



Procurement Plan (Draft)

Procurement Plan (Draft)

Procurement Equipment

In this Procurement Plan, equipments which doesn't required field survey are included as shown in the tabel below.

Installation Order	Countermeasure Equipment	Remote Procurement	Guidance/Advice on Site
1	Over Current Indicator (OCI) Abrasion Resistance Cover for Conductor	possible	Abbreviation (remote)
2	Ground Fault Detector Enclosed Cutout Fuse	possible	Better (remote)
3	Fault Locating System Time Sequential Sectionalizer	impossible	necessary

ARC: Abrasion Resistance Cover for Conductor

Conductor Cover for Way Leaves

item	Performance
Commercial frequency withstand voltage	Drying: 15kV x 1 minute, Watering: 10kV x 1 minute
Abrasion resistance	Outer layer 1000 times, Inner layer 500 times
Flame retardant performance	V-0 class

Reference URL: https://www.fujikura.co.jp/products/infrastructure/otherproduct/01/2044039_11376.html

2. Abrasion Resistance Cover for Conductor

[Overview]

This product is used to protect electric conductors and cables from trees, etc. by attaching it to electric conductors and cables that are adjacent to trees, etc.

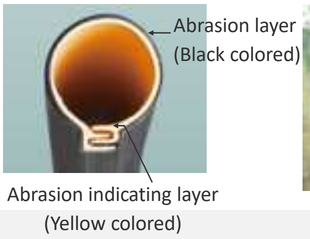
[Benefits]

-This product is made of flame-retardant materials. (V-0 class*)

-The two-layer construction (outer layer: black, inner layer: yellow) makes it possible to visually check the time of replacement due to abrasion.

-A locking mechanism is provided at the bottom of the joint to prevent it from opening.

* The flame-retardant grade is a measure of the degree of flammability of plastic materials used in equipment and appliances and is generally defined by UL94 standards. ***(Superior) 5VA > 5VB > V-0 > V-1 > V-2 > HB (Inferior)***

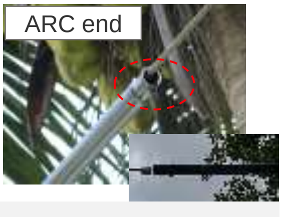


WG3-1: Technical Transfer by OJT on Site -OCI installation-

OJT of ARC installation on site

- Wire break down by contacting to a close pole in the same span due to wind blow.

Fix the conductor to the pole



OCI: Over Current Indicator

Equipment Procurement Plan

Since there is no prospect of travel to Sri Lanka, the equipment procurement plan will be carried out as shown in the table below.

Installation Order	Countermeasure Equipment	Remote Procurement	Guidance/Advice on Site
1	Over Current Indicator (OCI) Abrasion Resistance Cover for Conductor	possible	abbreviation
2	Ground Fault Detector Enclosed Cutout Fuse	possible	necessary
3	Time Sequential Sectionalizer Fault Locating System	impossible	necessary

The equipment to be procured is classified into three categories according to “whether or not it can be procured remotely” and “whether or not guidance and advice are required at the site (not installation instructions)”.

Therefore, only installation order 1 will allow remote procurement and installation. Installation order 2 can only be procured remotely. (The delivery to the CEB has been completed and the installation can be done immediately after the travel to Sri Lanka.) Installation order 3 does not allow for remote procurement and installation.

1. Over Current Indicator (OCI)

[Overview]
This product is an over current indicator (OCI) with a function to detect and display the overcurrent (short-circuit current) flowing in the overhead distribution lines, and to automatically recover after a certain period of time.

[Benefits]
Maintenance free (no batteries are required due to electromagnetic induction operation)
Applicable to bare conductors

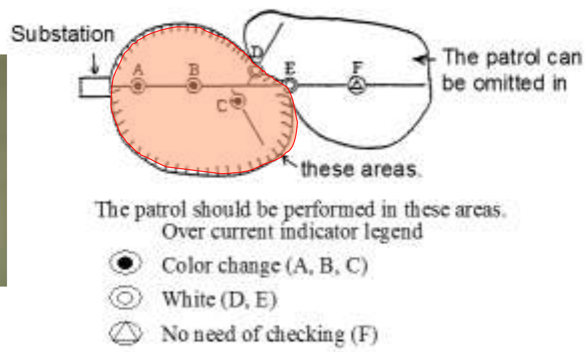

Image of attachment to a conductor

Rating

	300A	600A
Rated operating current	300A	600A
Min. detection current	250±30A	550±40A
Indicates retractor current	2A or more	
Indicates retreat time	5hours	
Overcurrent strength	12.5kA	
Rated frequency	50Hz	
Operating temperature range	-20~40℃	

1. Over Current Indicator (OCI)


display state
(When overcurrent passes)
hidden state
(Normal)



The color at bottom of the indicator is changed from white to red by the passage of short-circuit current through the parts behind the installation point.

So, The patrol should be performed in these red areas since there is no need to look at the latter part of the distribution line.
In this case patrol time can be cut in half.

Important announcement on OCI detection duration:

Guarantee level of detection time: 0.5 s or less

Actual performance level of detection time: 0.07~0.17 s

Proposal of OCI operation, as follows.

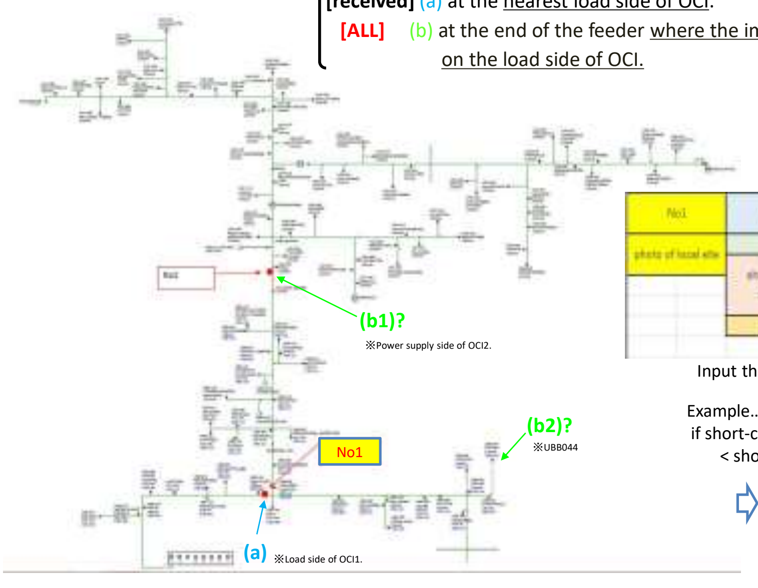
- If there is a detection display,
  there is a failure on the load side of the OCI.
- If there is no detection display,
  it is unknown whether there is a failure on the load side of the OCI.

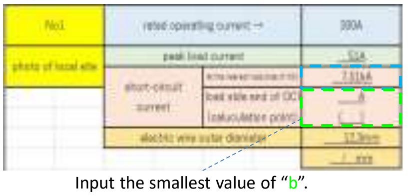
1. Over Current Indicator (OCI)

1-1 Short-circuit Current

[received] (a) at the nearest load side of OCI.

[ALL] (b) at the end of the feeder where the impedance is maximum on the load side of OCI.





Input the smallest value of "b".

Example…
if short-circuit current(b1:2.21kA)
< short-circuit current(b2:3.5kA)

2.21kA
(power supply side of OCI2)

WG3-1: Technical Transfer by OJT on Site -OCI installation-

WG3-1: Technical Transfer by OJT on Site -OCI installation-

OJT on site in case of ARC installation

-Please keep approx. 1 m away from the part where the wire splits downward.

-Please keep a distance of about 400mm between different phases.

-Please lessen a conductor sag, if it is deeper.

WG3-1: Technical Transfer by OJT on Site -OCI installation-

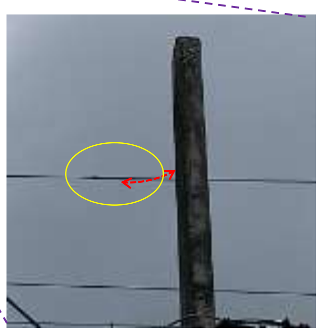
The possibilities of the sound from the installed OCI are:
・The wire thickness adjusted with tape instead of spacers might be too thick and doesn't fit well.
・There might be a slight gap.
・The core surfaces to connect each other might be dirty.

WG3-1: Technical Transfer by OJT on Site -OCI installation-

OJT of ARC installation on site

➢ Wire break down by contacting to a close pole in the same span due to wind blow.

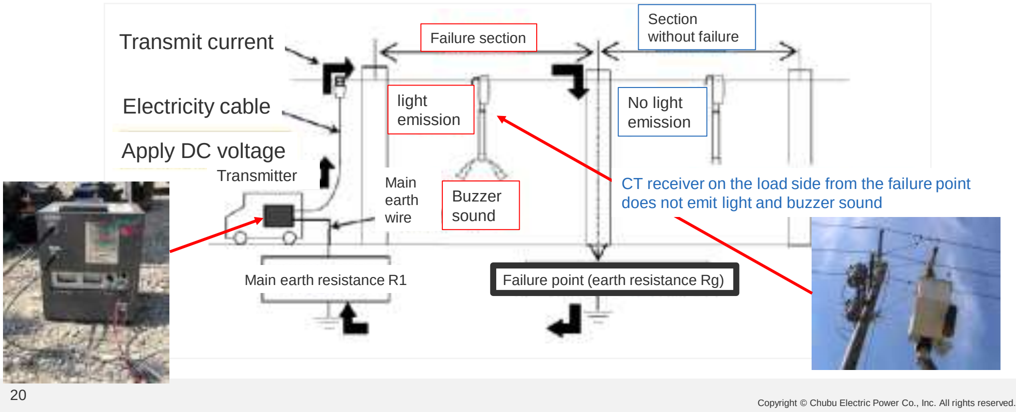
Fix the conductor to the pole



GFD: Ground Fault Detector

3. Ground Fault Detector (GFD)

DC voltage (5 to 15 kV) is applied to the high voltage line in the power failure section by the fault detector, and the ground fault current is received.
The cause of the failure is identified by the light emission and buzzer sound of the receiver. This makes it possible to identify damages and internal failures of the arrester, which are difficult to check with the naked eye.



3. Ground Fault Detector (GFD)

[Verification of Technical Issues on Real Lines]

-The applied voltage to the actual line path

→there is a possibility that this device can be applied to a complete ground fault on a 33kV distribution line.

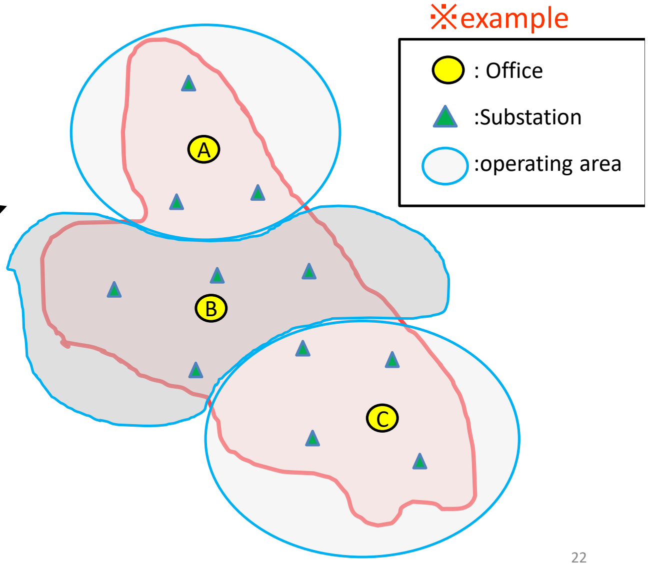
-The detection range of the charging system and the applicability of the distribution line length.

→It is effective to divide the distribution line into 30km or less or to install an overcurrent indicator separately.

*The detection method using GFD is shown in another data “20200908_Detection method of Ground Fault Detector”.

Confirmation : How to store, use GFD

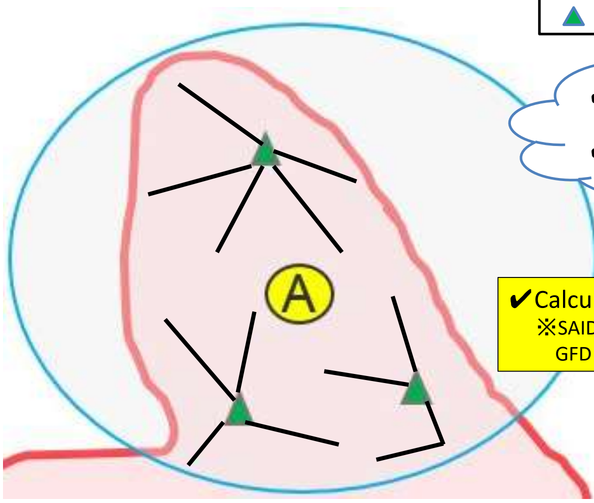
DD2 / Eastern / Batticaloa



Confirmation : How to store, use GFD

DD2 / Eastern / Batticaloa

: Office
: Operating area
:Substation
:Feeder



✔Store at....
Office? Substation? Other place?
✔ Use at which substation/feeder

✔Calculate current status(2019) of SAIDI
※SAIDI of each feeder where you will apply GFD in the pilot project

ECF: Enclosed Cutout Fuse

Enclosed Cutout Fuse

We thought DDLO installed in the primary side of the 11/0.4 kV transformer(substation) would be exchanged to enclosed cutout in the pilot sites. Is it right?

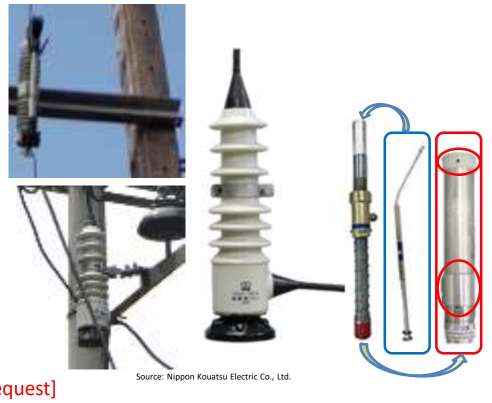
Enclosed Cutout Fuse

Causes in 11 kV lines which can be reduced by enclosed cutout instead of DDLO installed in the primary side of 11/0.4 kV transformer(T/F)

- Touching of birds, animals, tree, etc. to the exposed parts of DDLO
- Deterioration of DDLO(shown in photo) itself by ultraviolet, etc.
- Burnout of 11/0.4 kV transformer such as internal breakdown of primary winding, in case of no DDLO at primary side of T/F

Enclosed Cutout Fuse

[Overview]
Enclosed cutouts are installed in the primary side of an MV/LV transformer, in order to be able to isolate the transformer from the MV distribution line. An enclosed cutout is constructed with a fuse holder concealed by insulator. This can prevent equipment failure due to contact with flying debris, salt damage, etc.



Source: Nippon Kouatsu Electric Co., Ltd.

Specifications of ECF

-Rated Voltage	:	12kV
-Rated Current	:	50A
-Rated Frequency	:	50 / 60Hz
-Fuse Link Amperage	:	6A - 50A (max)
-Ambient Temperature	:	-20°C ~ +40°C
-Altitude	:	< 1000m
-Operation Cycle (at no load)	:	> 500 times
-Increase Temperature	:	60°C
-Rated Interrupting Current	:	12.5kA, 3times
-Load Break	:	50A / 15 times,65A / 5 times
-Power-frequency Withstand Voltage	:	42kV (to earth and between pole)
	:	48kV (Across isolating distance)
-BIL (Basic Impulse Level)	:	75kV (to earth and between pole)
	:	85kV (Across isolating distance)
-Interrupting Capacity (Sym Current)	:	12.5kA
-Creepage Distance	:	280mm (25mm/ kVx11.2)
-Weight	:	4.2kg

[Request]
To connect the cutout to the equipment, please send us construction drawings and photos of the transformer primary.

How to Break Load Current (Turn on and off)

By inserting the top of an operation rod into the bottom of a ECF from the ground, line can be turned on and off and the load side of the enclosed cutout is isolated.

Source: Nippon Kouatsu Electric Co., Ltd.

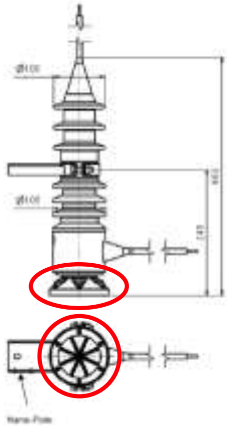
Opening operation
(Turn off)

Closing operation
(Turn on)

Source: NGK insulators, Ltd.

How to Check Drop-out Action of Enclosed Cutout Fuse

Fuse carrier part is dropped out, when the current flowing through an enclosed cutout exceeds the fuse capacity and the make fuse drop out as a proper action.



Source: Nippon Kouatsu Electric Co., Ltd.

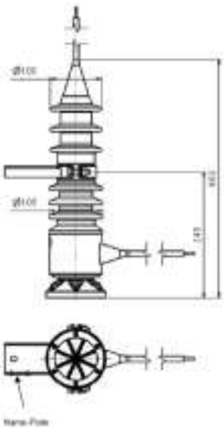
Source: Nippon Kouatsu Electric Co., Ltd.

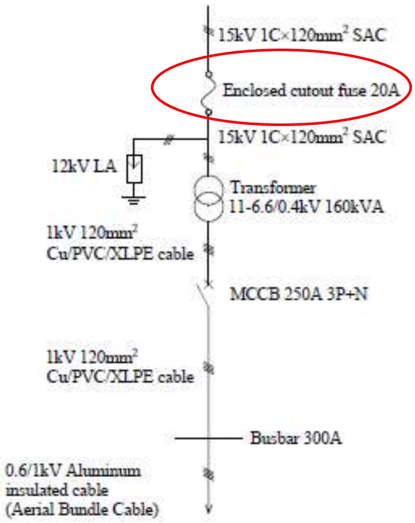
Source: NGK insulators, Ltd.

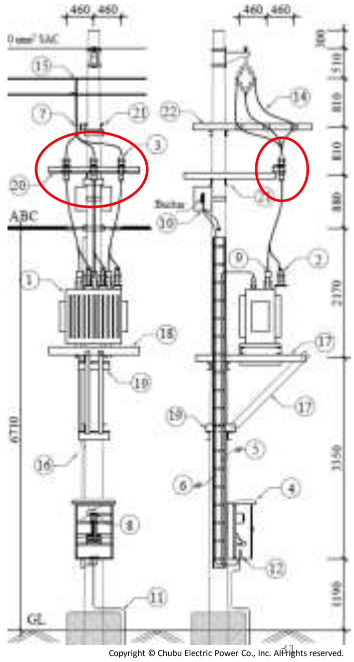
State of Dropped out

Enclosed Cutout Fuse

Drawings of cutout
installed in the primary side of transformer

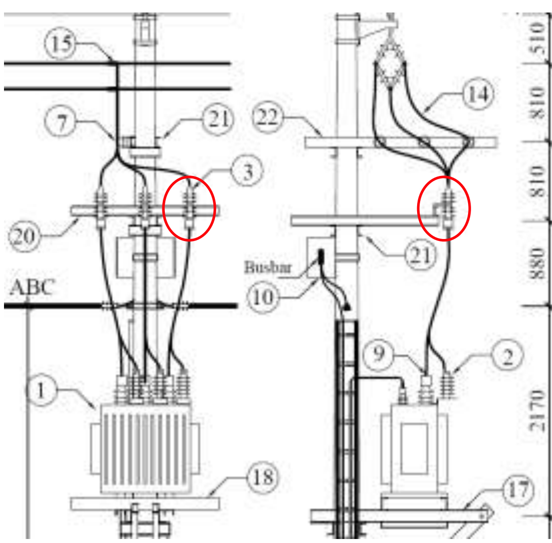


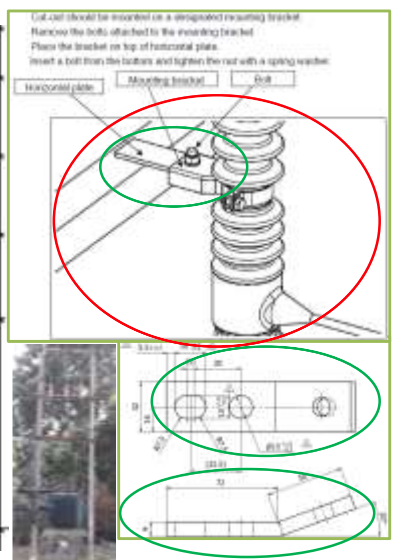




Enclosed Cutout Fuse

How to attach the mounting bracket to the cutout

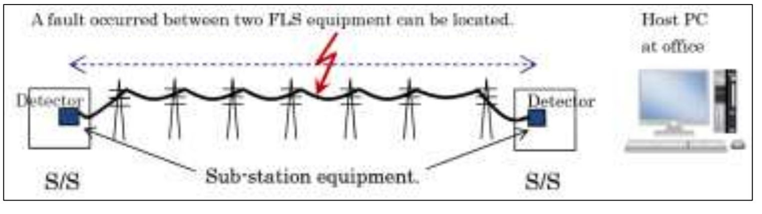




FLS: Fault Locating System

6. Fault Locating System (FLS)

[Overview]
- Locates and indicates faults on transmission and distribution lines;
- Consists of fault detectors installed at substations and Host PC placed at a regional maintenance & service office;
- Capable of detecting faults occurred on the line that has a detector at either end.



[Advantage]

FLS reduces losses from outages and the overall cost of line maintenance.

-Accurate Locating

-Efficient Fault Locating Work = Fast Service Restoration & Personnel Cost Saving

-Detection of Various Fault Types

6. Fault Locating System (FLS)

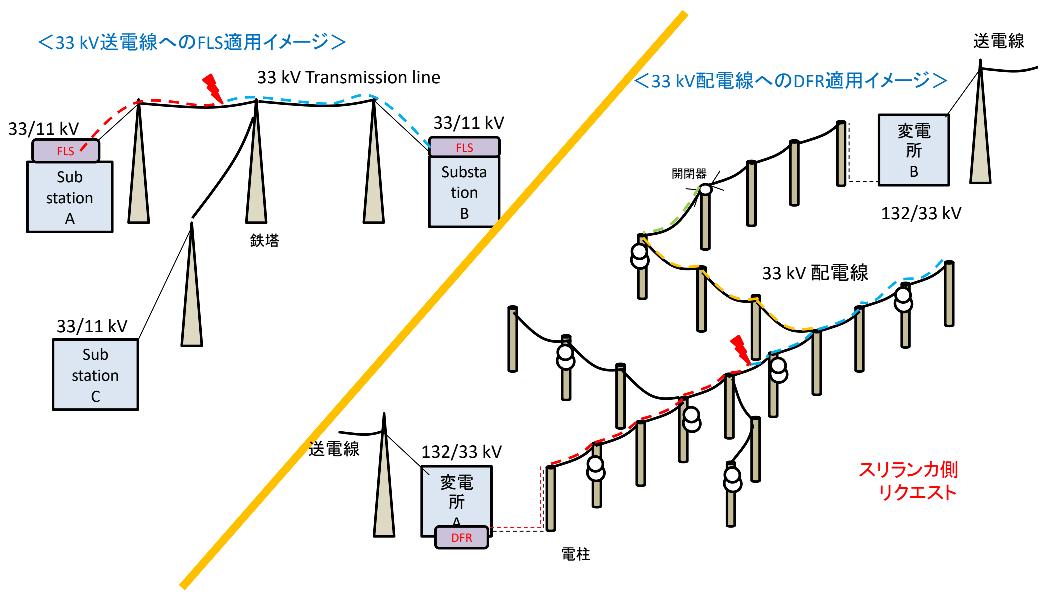
[Selection criteria]
Feeder with large transient current such as lightning, etc., rather than a failure caused by contact with another object

[Conditions of application]
-It is possible to take in CT3ϕ and VT3ϕ at each terminal.
-It is possible to take in CB contact information or protection relay contact information at each terminal.
-The grounding method shall be either direct grounding, resistance grounding, or grounding transformer.
-The SFL(Surge Failure Locator) and the server should be able to communicate with each other via IP network.
-It should be able to receive GPS signal.
 (It may be difficult to receive GPS signals in mountainous areas.

*Finally, need to check the distribution system diagram

[Request]
Please send us about your grounding system and fault detection system.

5. Fault Locating System (FLS)



4. Fault Locating System (FLS)

Fault Locating System : AMT7000
Normally, use in Transmission Line where MV/LV transformer and many branch don't exist.

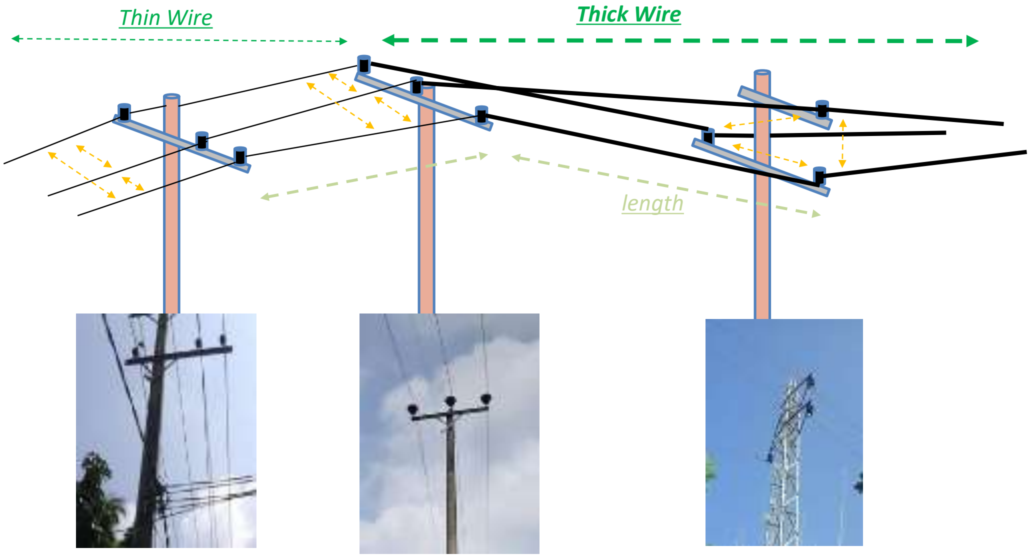
Concerns for introducing.

- ✔ It is necessary to know the detailed wire information of the target distribution line.
  details are such as Distance between wires, Thickness and length of wires for all span.
- ✔ Since the distance is measured by the impedance value of the MV, it cannot be applied in the case of an LV failure.
  (due to the impedance of the transformer affects the measurement of distance)
- ✔ Since it is not possible to distinguish between LV and MV failures when a failure occurs, the failure point is displayed even when an LV occurs.
- ✔ It is expected that repeated maintenance will be required to improve accuracy.
  ※ The error(10%) of the initial setting value (impedance) leads to the error(10%) of the distance of the failure point.

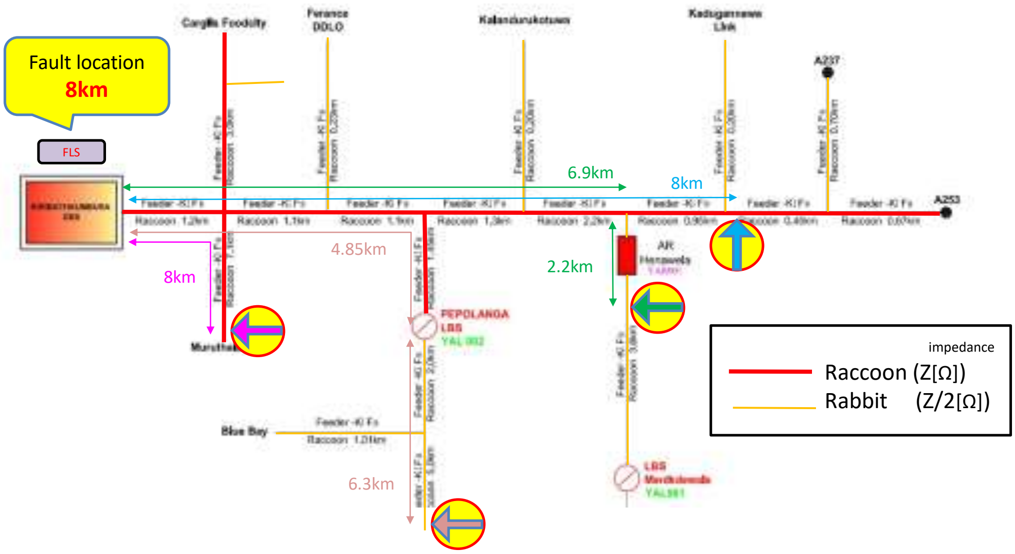
  It is necessary to identify the actual location of the power failure cause to correct the set value from the error between the distance indicated by the fault locator and the actual distance.

Distance between wires, Thickness and length of wires for ***all span***

FLS

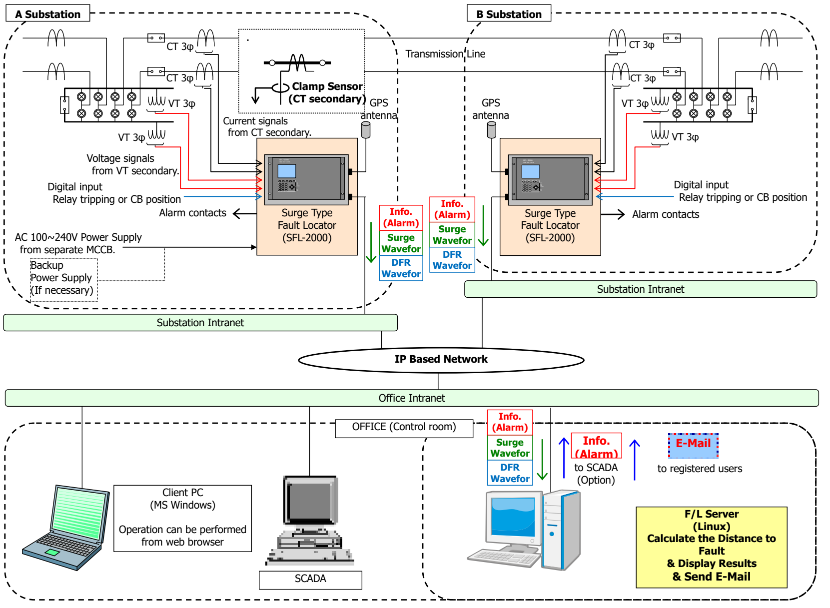


FLS

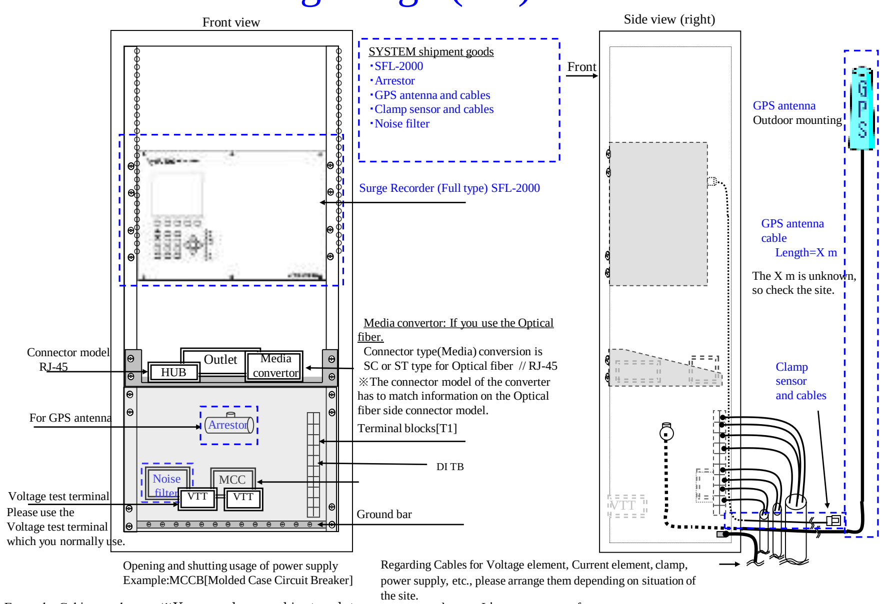


Configuration of Fault Locating System for the Pilot MV feeders

1. System Configuration

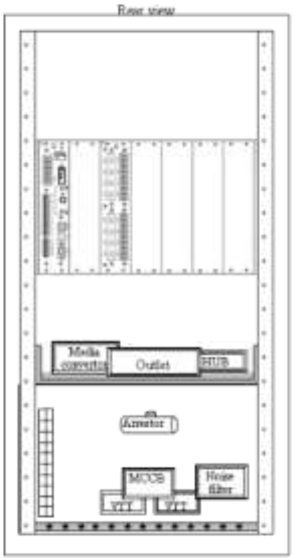


2. Rack Mounting Image (1/2)

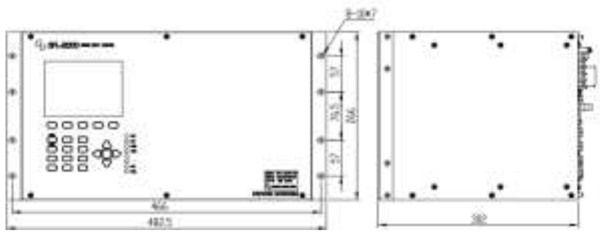


Example: Cabinet rack type ※You can choose cabinet rack type or open rack type. It's up to your preference.

2. Rack Mounting Image (2/2)



	Dimension
SFL-2000	482.5(W)×266(H)×302(D) mm For 19 inch rack type

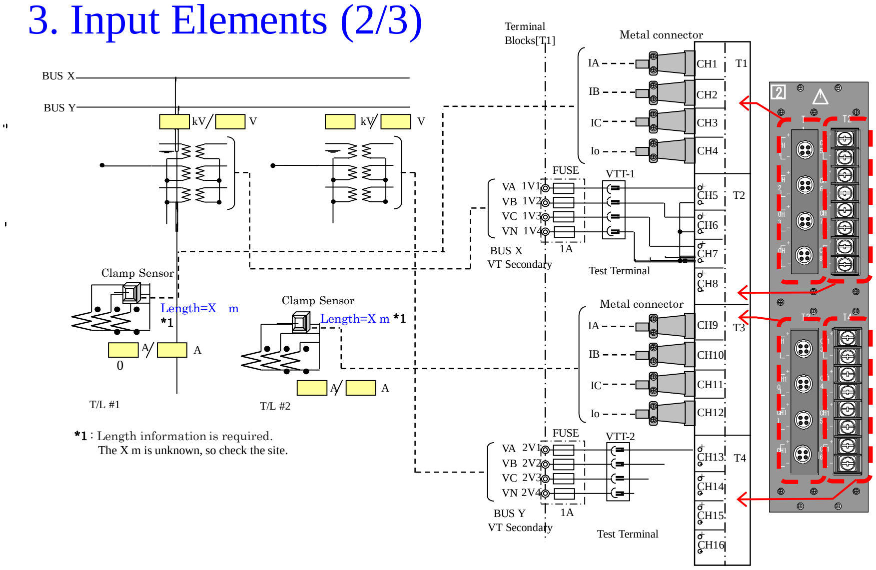


7. Input Elements (1/3)

Kind	Element	Purpose
Analog Input	3-phase Line Current Zero-phase Line Current (I_a, I_b, I_c)	●Fault location calculation ●Fault detection (Current surge detection) ●Fault detection (Current RMS Level detection)
	3-phase Bus Voltage (V_a, V_b, V_c)	●Fault location calculation ●Fault detection (Voltage surge detection) ●Fault detection (Voltage RMS Level detection)
Digital Input	Protection relay tripping or Circuit breaker status	●For fault detection, and fault phase determination.

●Input Elements are configurable

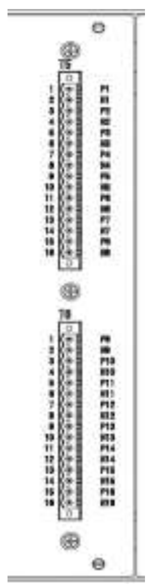
3. Input Elements (2/3)



3. Input Elements (3/3)

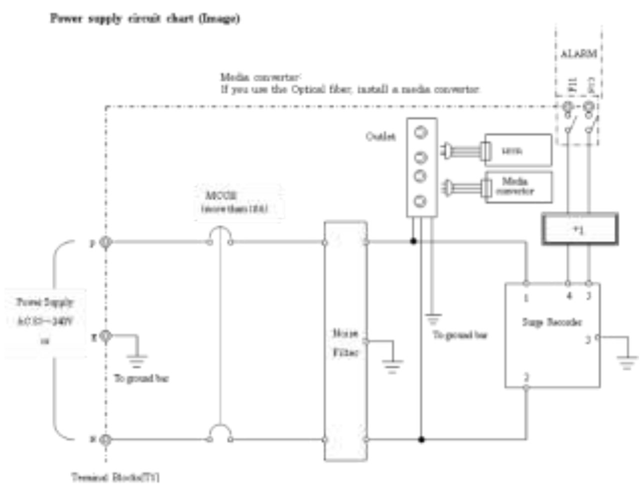
DC element

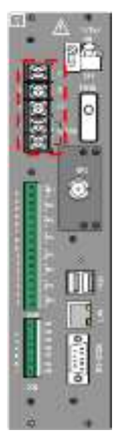
Voltage	from 110Vdc to 220Vdc	
Continuous overload	300Vdc	
Threshold	ON	80Vdc or higher
	OFF	30Vdc or lower
Input impedance	30k ohms or more	
Burden	0.5W or less (at 110Vdc)	



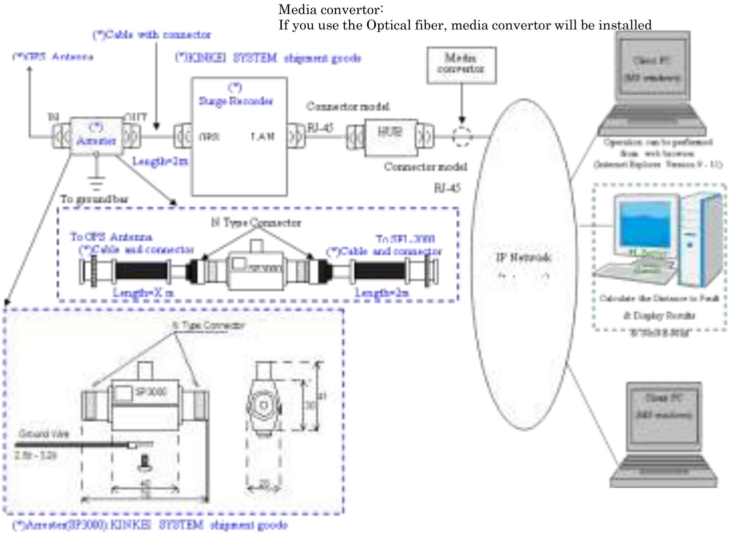
4. Clamp sensor

5. Power Supply





6. GPS cable, LAN



7. Supply Criteria of equipment (1/2)

Item	Location			Delivered by	
	A S/S	B S/S	Office	Manufacturer	Local argent or CEB
SFL-2000 Surge recorder	x	x		x	
GPS Antenna	x	x		x	
Debe Clamp for GPS Antenna Arrestor	x	x		x	
Cable between GPS antenna and arrestor	x	x		x	
Cable between SFL-2000 and arrestor	x	x		x	
Self-fusing tape for GPS antenna	x	x		x	
Clamp CT with cable	x	x		x	
Noise filter	x	x		x	
Panel for SFL-2000	x	x			x
MCCB (Molded Case Circuit Breaker	x	x			x

7. Supply Criteria of equipment (2/2)

Item	Location			Delivered by	
	A S/S	B S/S	Office	Manufacturer	Local argent or CEB
Outlet	x	x	x		X
Terminal Blocks	x	x			X
Voltage Test Terminal	x	x			X
4 cores VT cable	x	x			X
Power supply and Ground cable DC 110V - 220V or AC 100V - 240V	x	x			X
Network HUB	x	x	x		X
LAN cable for SFL-2000 and F/L Server	x	x	x		X
Media converter (option) *If the customer uses optical fiber cable, media convertor should be installed.*	x	x	x		X
F/L Server hardware (Linux server)	x	x			X
Red Hat Enterprise Linux 7.6 (64bit) for F/L server			x		x
F/L server software			x	x	

8. Work Criteria

Equipment name	Action Item	Manufacturer	Local argent or CEB
SFL-2000	Installation	(x)	x
	Calibration	x	x
	Test	x	(x)
F/L Server	Server hardware Installation		x
	Red Hat Enterprise Linux Installation		x
	Application Software installation	x	
	Test	x	

- Please arrange a digital voltage/current generator and a digital voltage/current meter to the substation.
- The manufacturer will use them to perform calibration of SFL-2000.

9. Installation and Test Schedule

An example schedule at site

Location	Task	DAY											
		1	2	3	4	5	6	7	8	9	10	11	12
A Substation	Installation Panel, GPS antenna, SFL-2000, VT/CT cabling	↔	↔										
	SFL-2000 Test						↔	↔					
B Substation	Installation Panel, GPS antenna, SFL-2000, VT/CT cabling			↔	↔								
	SFL-2000 Test								↔	↔			
Office	F/L server Installation					↔							
	F/L Server Test					↔					↔		
Classroom	Training											↔	

To dispatch an engineer to CEB on this date

10. Services(1/2)

① Initial Data Setting

The manufacturer shall set the parameters.
For example, overhead line length, transmission line name, surge speed, device definition, threshold level.

② Training

- Place

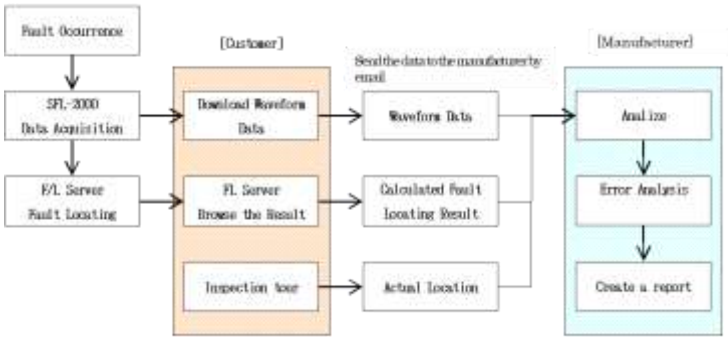
  Classroom where connection to XXXXX network is available in order to access F/L server and SFL-2000.

- Contents
  - System overview
  - F/L Server Operation
  - SFL-2000 Operation
  - How to download data

10. Services (2/2)

③ Fault Locating Result Analysis Support

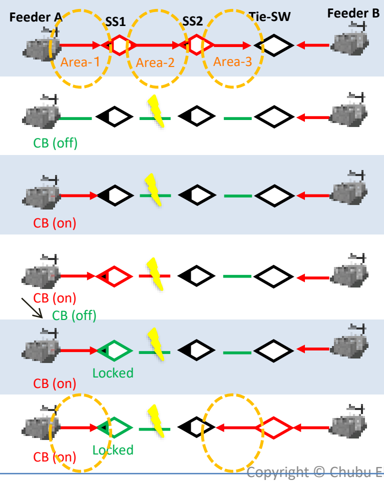
- When a fault occurs, the customer shall download the recorded waveform data from the F/L server. Then the customer shall send the downloaded data, calculated fault location and the actual fault location to the manufacturer by e-mail.
- The manufacturer shall analyze the data and create a report and send it to the customer.
- When the locating error is not negligible, the manufacturer shall pinpoint the cause of the error and shall suggest the setting parameter change.



TSS: Time Sequential Sectionalizer

What is TSS? - Automatic Early Recovery against Fault Outage -

TSS sectionalizes a fault section area automatically.
(detects and isolates)

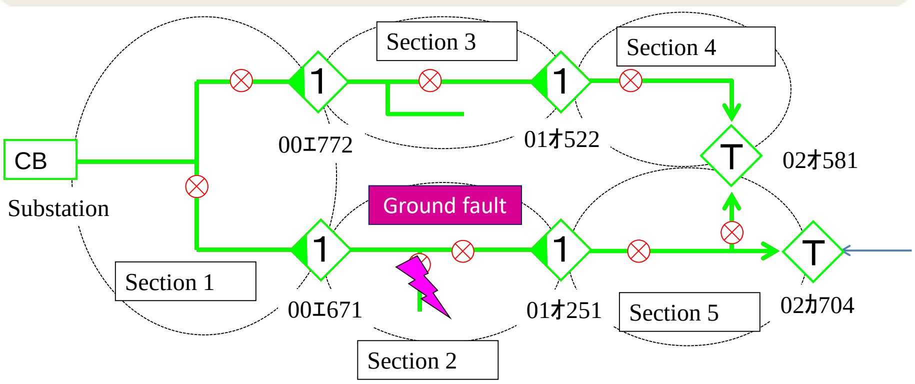


Process	Power Flow	Automatic Action
(1) Normal	Feeder A, SS1, SS2, Tie-SW, Feeder B, Area-1, Area-2, Area-3	Suppose, Feeder-A is divided into 3 section areas by 2 section switches (SS). Feeder-A is tied to Feeder-B via Tie SW.
(2) Trip	CB (off)	If a fault occurs in Area 2, the relay at S/S detects a fault and makes the circuit breaker (CB) trip at S/S. All SSs also get opened as their powers get off.
(3) Reclose	CB (on)	In 60 seconds after the fault detection, the CB gets closed automatically and Area1 gets energized.
(4) Re-Trip	CB (on) CB (off)	In 9 seconds after Area1 gets energized. SS1 gets closed automatically and Area2 gets energized. However, the CB trips again because Area 2 has the fault. At this time, <u>SS1 memorizes that Area 2 is a fault area and keeps its own state off (Locked)</u>.
(5) Reclose again	Locked, CB (on)	In 60 seconds after the second fault detection, the CB gets closed automatically and Area1 is energized. But SS1 never re-close.
(6) Inverse	CB (on), Locked	If the Feeder A side of Tie-SW is kept off in a certain time, Tie-SW closes automatically, and Area 3 gets energized. Thanks to TSS, Area 1 and 3 can be supplied power automatically.

(1) Outbreak of Distribution Line Fault

☆ Suppose a ground fault occurred in Section 2.

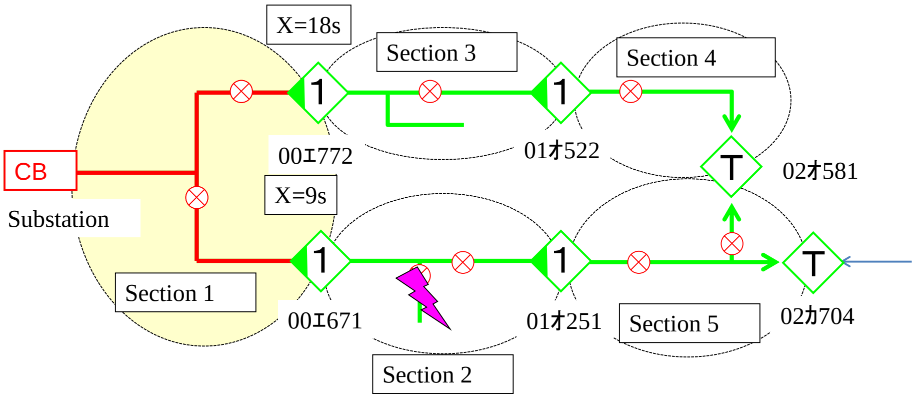
☆ Protection relay installed in the substation detects the ground fault.
☆ The circuit breaker in the substation intercepts the distribution power.
☆ The distribution line area looses power.



(2) Reclose of Circuit Breaker

☆ The circuit breaker is closed in 60 seconds after it intercepted.

☆ When electric power is supplied to the power source side of the Section Switches, they start to count the given times (called : X time limit [multiple of 9 seconds]) and then are closed in order.

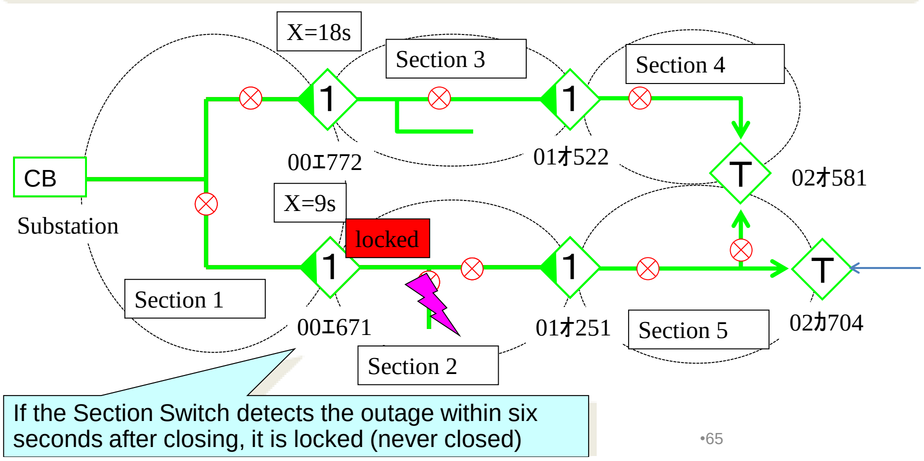


•64

(3) Reopen of Circuit Breaker (Detection of a Fault Section)

☆ The Section Switch (00エ671) gets closed after 9 seconds.

☆ The protecting relay detects the fault again, since the fault is in section 2.
☆The Circuit Breaker gets opened again.

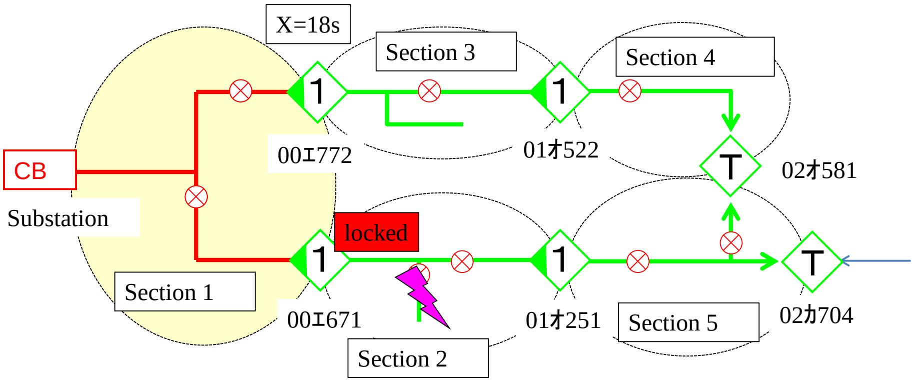


•65

(4) Re-reclose of Circuit Breaker

☆ The Circuit Breaker is closed again after a given time.
（about 140 seconds after the first open）

☆The Section Switch (00エ772) starts counting X time limit (18 seconds).

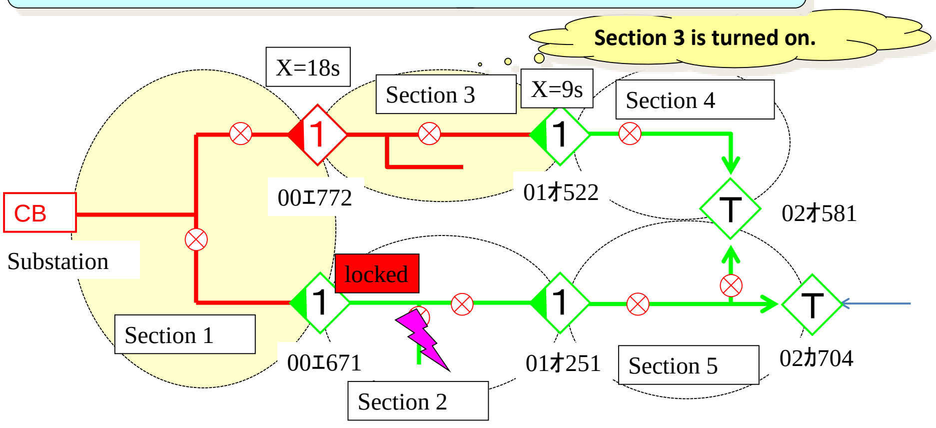


•66

(5-1) Power Distribution in No Fault Sections

☆ Section Switch (00エ772) is closed after 18 seconds.

☆ Section Switch (01オ522) start counting X time limit (9 seconds).



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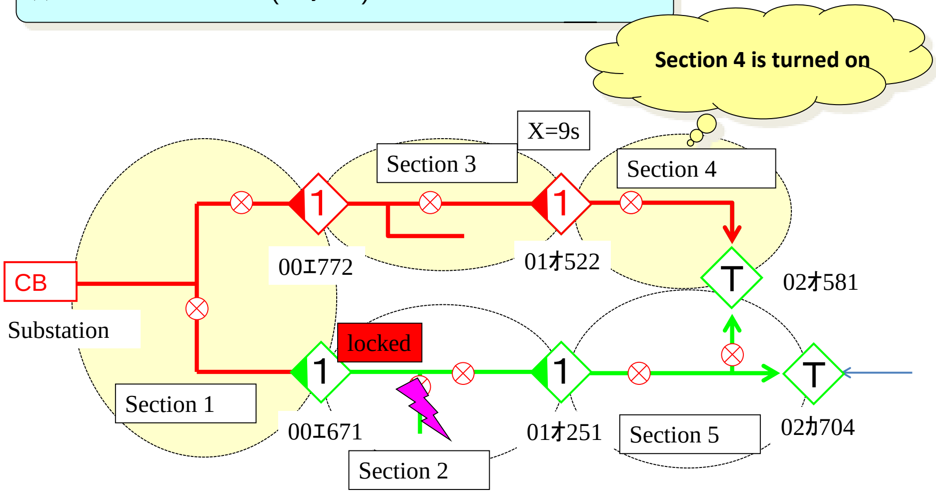
(5-2) Power Distribution in No Fault Sections

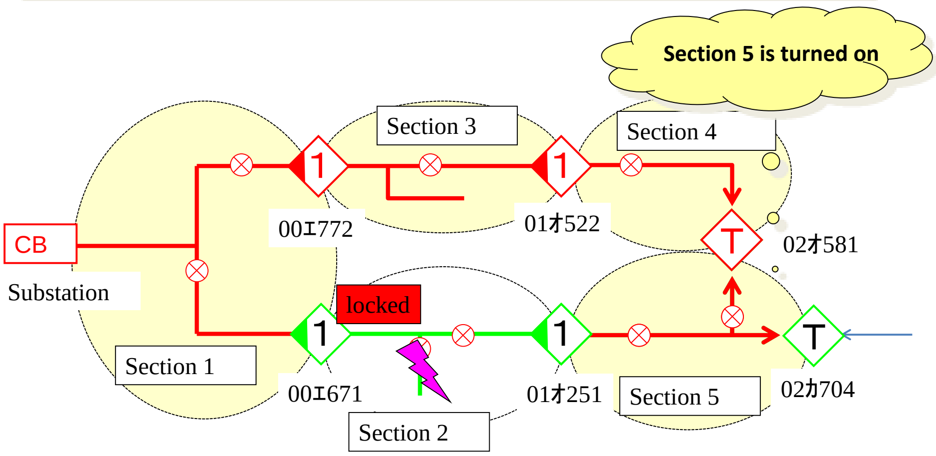
☆ The Section Switch (01オ522) is closed after 9 seconds.



•68

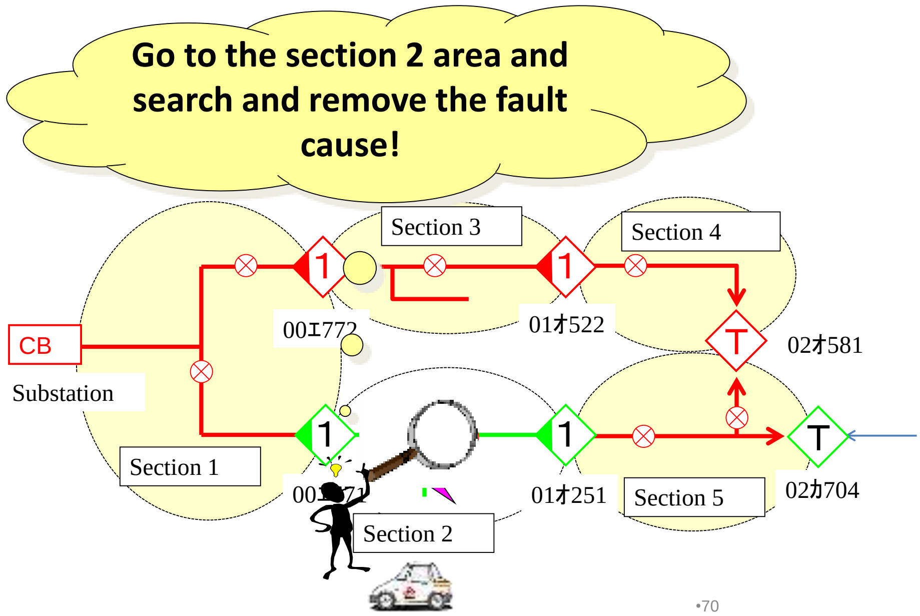
(5-3) Power Distribution in No Fault Sections

☆ The Section Switch (02オ581) is closed by the remote operation at the office



•69

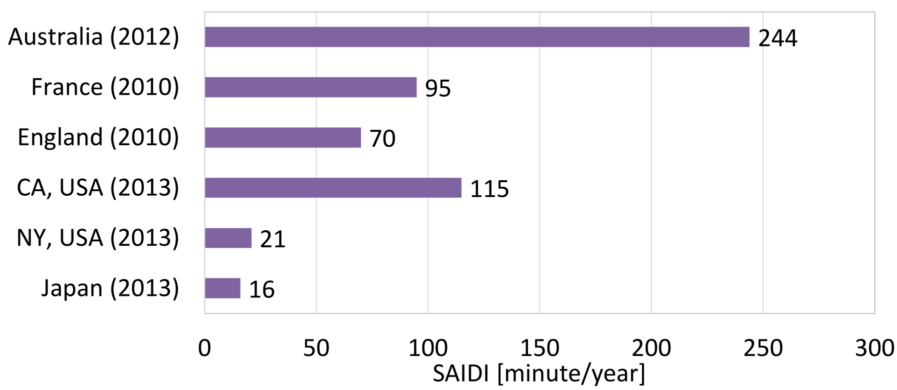
(6) Investigation of Fault



Time-Proven in Japan and Standardized in IEC

Time Sequential Sectionalizer (TSS), having been working in all the Japanese electric power companies, has time-proven performance.

TSS was standardized as IEC 61850-90-6 in 2019.



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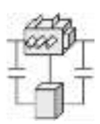
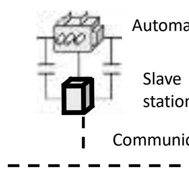
TSS Introduction Steps from the First to the Future

TSS can be upgraded step by step, according to progression of other infrastructures of communication line, smart meter system, etc.

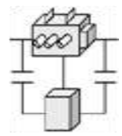
Step	Available method	Data transfer	Remote supervisory and control	Remarks
1	Time sequential sectionalizer	No need (Work by themselves)	Will be possible by upgrading	To be verified in the pilot project
2	Remote supervisory and control	Utilization of existing N/W (Low speed)	Possible by manual operation remotely from control center	No restriction by existing infrastructure
3	Automatic supervisory and control	Need of progression（High speed and Large capacity）	Possible by automatic operation from control system Furthermore, possible to enhancement of power quality as well as supply reliability by linking to other systems	Link to other systems such as smart meter system

History of distribution automation system introduction in Japan

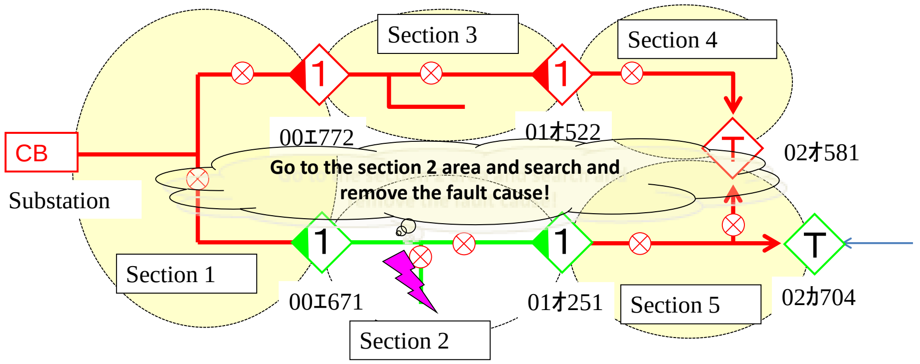
	Phase Ⅰ	Phase Ⅱ
Image		
Time Sequential Sectionalizer	○	○
Communication function	×	○
Overview	No introduction of distribution automation system -Operating all switches and SVRs on site -When an accident occurs on a distribution line, the time-sequential forwarding method is used to disconnect the accident section	Started installation of communication infrastructure and distribution automation system -Remote monitoring and control of automatic switches from business sites -In the event of a distribution line accident, the distribution automation will automatically send back from the master station.

5. Time Sequential Sectionalizer

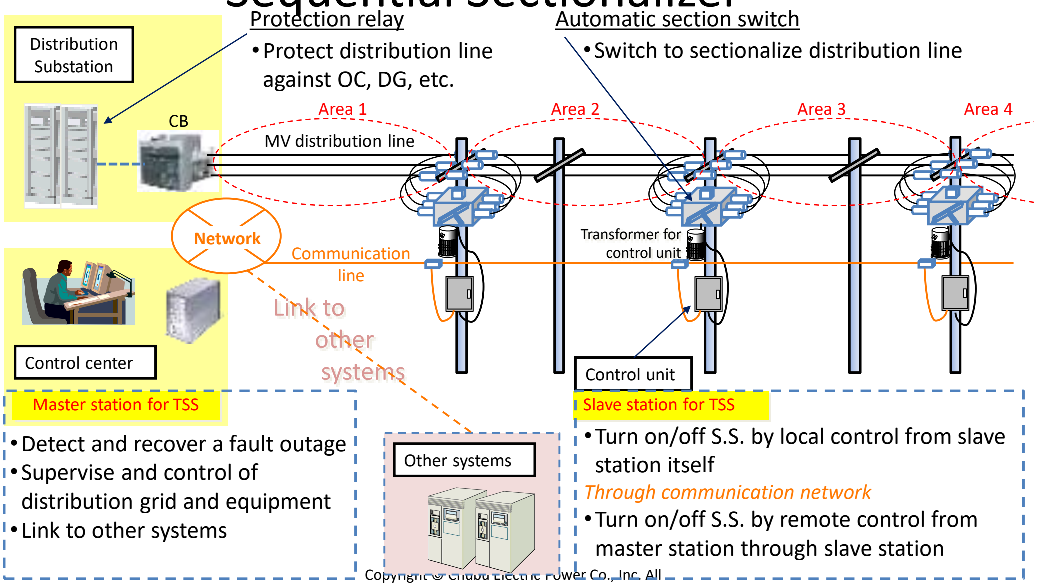
[Selection Criteria]
-Can be sent in reverse in conjunction with other feeders
-With essential load
-Selection at both 11 and 33 kV



[Request]
In order to develop relays to match existing CEB switchgear, we would like to know the specifications of the switch that can recognize the input/output signal information.



Whole Configuration of Time Sequential Sectionalizer

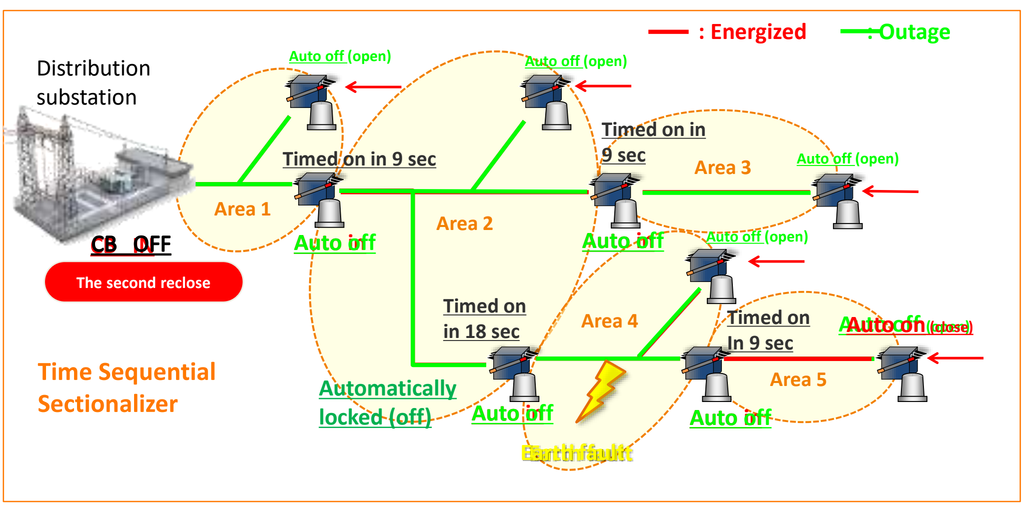


Step 1

◎Improvement of power supply reliability

by operation of equipment itself without communication network

Step 1: Improvement of power supply reliability by TSS



TSS can detect and isolate a fault outage section and can supply power to some other sections automatically without communication network.

From Step 1 to Step 2

Step 1

◎Improvement of power supply reliability

by operation of equipment itself without communication network

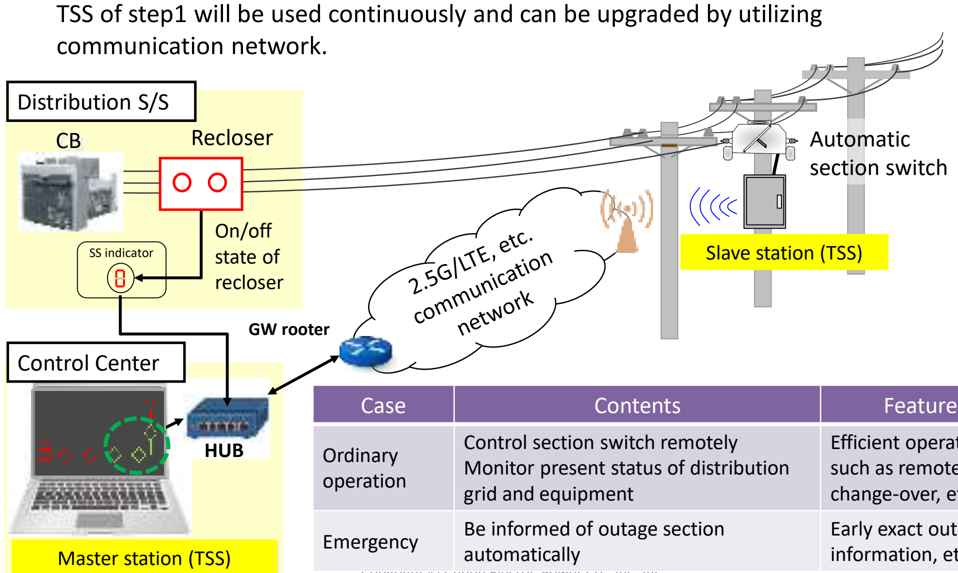
Step 2

◎Further improvement of ordinary operation

by supervisory and remote control of section switches with existing communication networks

Step 2: Further Improvement by TSS Upgrade

TSS of step1 will be used continuously and can be upgraded by utilizing communication network.



Case	Contents	Features
Ordinary operation	Control section switch remotely Monitor present status of distribution grid and equipment	Efficient operation such as remote grid change-over, etc.
Emergency	Be informed of outage section automatically	Early exact outage information, etc.

From Step 2 to Step 3

Step 2

◎Further Improvement of ordinary operation

by supervisory and remote control of section switches with existing communication network

Step 3

◎Sophistication of **power supply reliability**

◎Sophistication of **power quality** in preparation for VRE

by linkage to other systems
with conditions of high-speed and large-capacity data transfer infrastructure

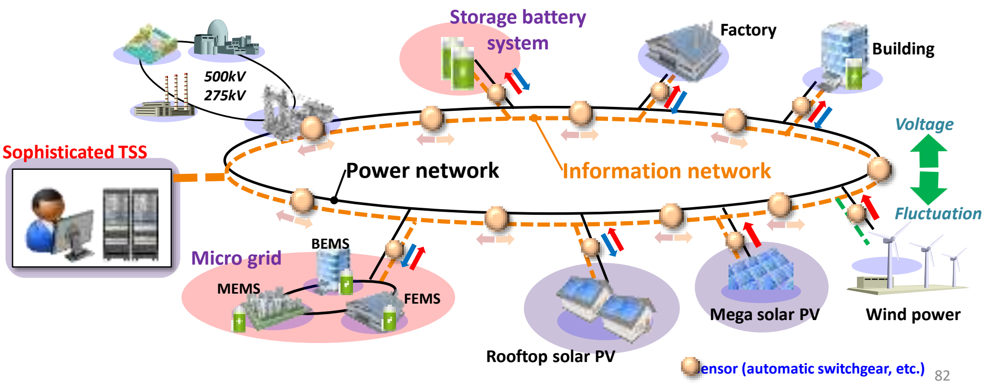
Step3: Power Quality Problems by Mass VRE Interconnection

Voltage fluctuations and rises are getting more pronounced by mass introduction of VRE.

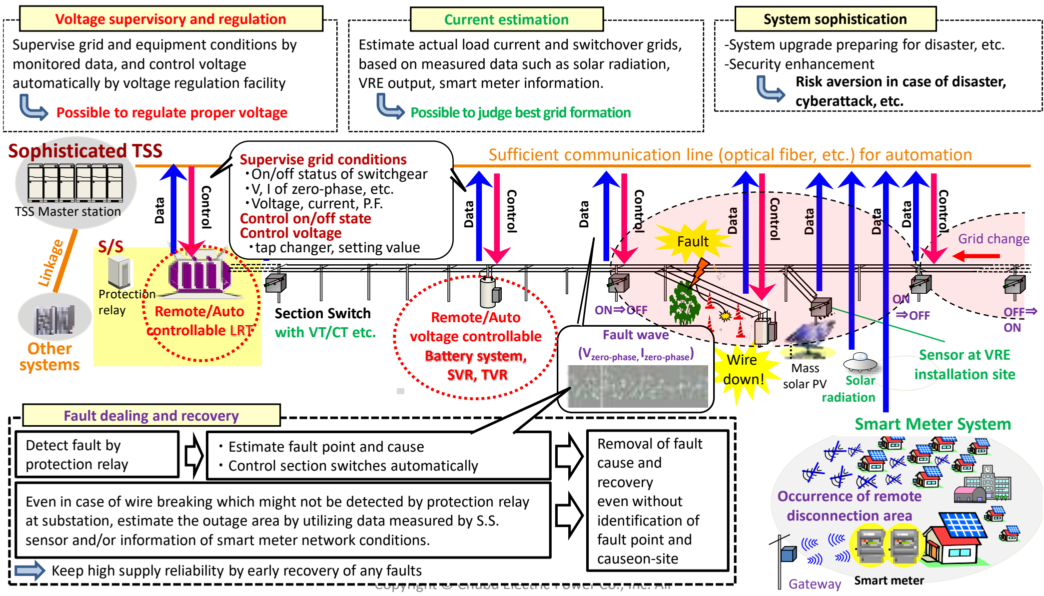
Electricity usage is getting more diversified by attracting microgrids, demand response, etc.

There is concern that **voltage management** in distribution systems will be getting more and more complicated in the future.

Therefore, to ensure and keep power quality as well as power supply reliability will be strongly requested in the future.



Step 3: Future Image of Sophisticated TSS



Introduction Status of SCADA for Distribution Networks

Division/ Province	DD1				DD2				DD3			DD4		LECO
	CC U/G	NWP	NCP	NP	CP (Kandy)	CP (others)	**WPN**	EP	**WPS2**	Sub	Uva	**WPS1**	SP	**LECO areas**
SCADA	Spectrum Power4.5 - Siemens - installed in 2012 - Only 5 CCs	micro-SCADA - made by NortRoll - Firstly installed in 2009			ifix - by GE	No SCADA Devices Operated through proprietary software	Genisis64 - by ICONICS	SCADA is not available Auto-recloser, LBS and FI are communicated via its own proprietary software	ifix - by GE	micro-SCADA - by NortRoll	ifix - by GE			Included in the upcoming donor funded project
Versatility	High - Link to Recloser, Fault I indicator, etc.	Low - Longtalk Protocol (low versatility) - Link to Enstro's SS only - No linkage among control centers(CCs)			High - Link to Recloser, Fault I indicator, etc.	Moderate -3G Link to Auto reclosers and Load Break Switches	GPRS/3G Link to Auto re closures	Low	High - Link to Recloser, LBS, Primary etc. Planned to connect NSCC	Low - Link only to Enstro's switch - No linkage among CCs				
Supervisory/control of SS, Gantry, FI, upstream grid outage														
Extensity					High -Link to several protocol	High -Link to several protocol			High -Link to several protocol		High -Link to several protocol			
Recloser/ Section Switch(SS)	- Several vendors - Open platform	Enstro (France) - Automatic switch - Connected to SCADA Others' - No connection to SCADA			- Several venders - Open platform	- Several venders - Open platform		- Several venders - Open platform	- Several venders - Open platform		- Several venders - Open platform			Piloted successfully and in the process of implementation for all the remotely operable ARs
Telecommunication									3G Cellar? Inferior in realtime reliability					
Smart meter (verification stage)					Wireless multi-hop									GPRS, Wireless multi-hop (zigbee)
Developing status for CCs	100%	100%	100%	100%	Legacy Devices are not connected	Developing	80%	Designing	100%	100%	Designing	Designing	Under consideration	Under Development

6. Time Sequential Sectionalizer

5.3. Technical Parameters

CEB specification 078 2019

	Technical Parameter		AR		LBS-SF	
(a)	Rated Voltage	kV	12	33	12	36
(b)	Frequency	Hz	50	50	50	50
(c)	Continuous Current Rating	A	400	400/800	400	400
(d)	Rated Short Circuit					
	(i) Breaking current RMS	kA	12.5	16	0.4	
	(ii) Making Current Peak	kA	31.5	40	31.5	40
(e)	Short Time Current (1 Second)	kA	12.5	16	12.5	16
(f)	Insulation Level					
	(i) Impulse withstand voltage (1.2/50 s) kV peak	kV	75	170	75	170
	(ii) Power frequency withstand voltage wet (1min.)	kV	28	70	28	70
(g)	Insulator creepage distance	mm	300	900	300	900

Smaller specifications cannot be accepted soon.

5.1. General Design Features / Requirements of AR and LBS-SF.

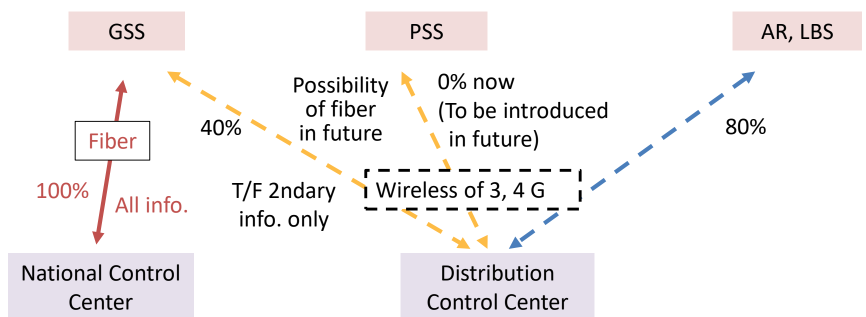
CEB specification 078 2019

	Requirement	AR	LBS-SF
(i)	Operating Chamber	The AR shall have self-contained recloding chamber or chambers for each phase including operating mechanism, hermetically sealed.	The LBS-SF shall have self-contained switching chamber including operating mechanism hermetically sealed.
(ii)	Interrupting Medium	Shall be Vacuum only	Shall be Vacuum/SF₆
(iii)	Current Transformer /Sensor	CT sets for each phase to measure current and enable overcurrent, earth fault, sensitive earth fault and directional protection schemes.	CT/Current sensor sets for each phase for current measurements and to detect earth fault.
(iv)	Voltage Transformer /Sensor	VT/Voltage sensor sets for each phase on both sides to measure voltage and enable over/under voltage and directional protection schemes and to find energization of both sides. An over voltage trip setting of 100% up to 150%, in steps of 1%, above the nominal system voltage. The under voltage setting range of 50% to 100%, in steps of 1%, below the nominal system voltage shall be provided.	VT/Voltage sensor sets for each phase on both sides to measure voltage and enable over/under voltage and to find energization of both sides.
(v)	Protection Schemes		

No need of functions of current/voltage measurement

Progress of SCADA Communication Infrastructure

Introduction progress in the communication infrastructure for SCADAs



Applied international protocol: DNP3, IEC101, IEC104, Modbus

Procurement Schedule for Each Equipment

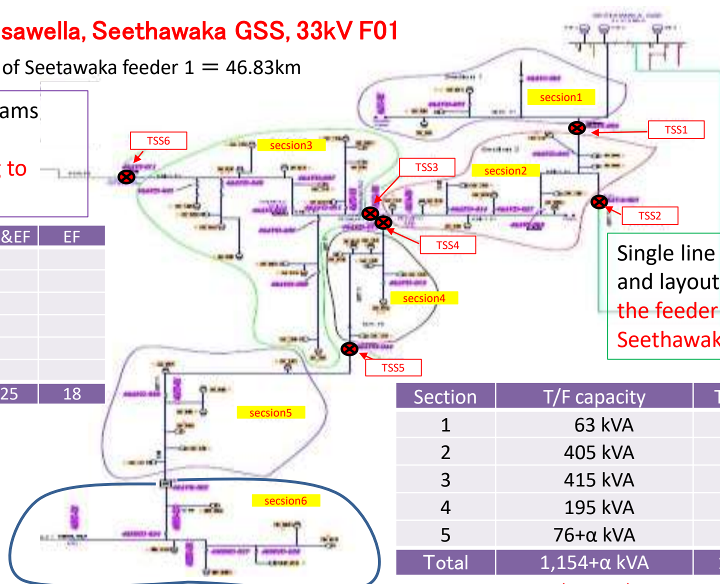
6. Time Sequential Sectionalizer

WPSII, Avissawella, Seethawaka GSS, 33kV F01

Length of Seetawaka feeder 1 ＝ 46.83km

Single line diagrams and layouts of the feeder tying to Seethawaka F1

	OC	OC&EF	EF
S1			
S2			
S3			
S4			
S5			
S6			
Total	33	125	18



Single line diagrams and layouts of the feeder tying to Seethawaka F1

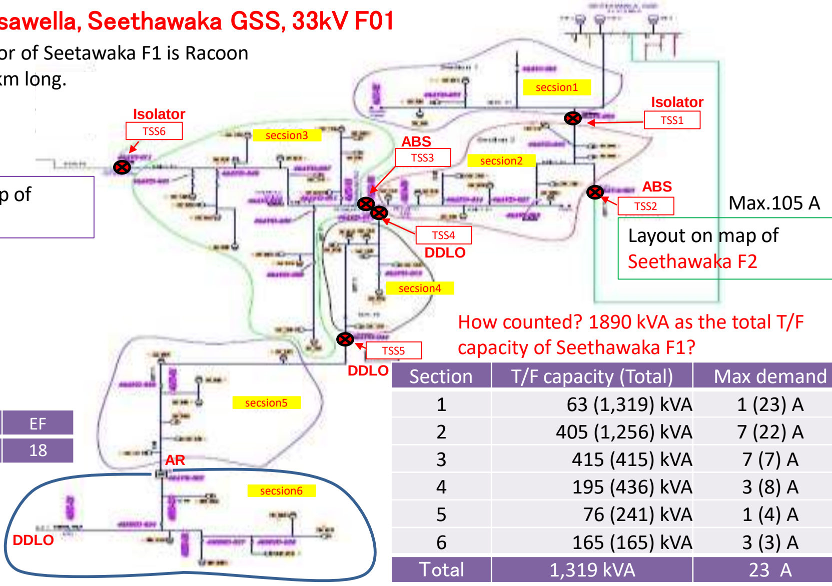
Section	T/F capacity	Total capacity
1	63 kVA	1,154+α kVA
2	405 kVA	1,091+α kVA
3	415 kVA	415 kVA
4	195 kVA	271+α kVA
5	76+α kVA	76+α kVA
Total	1,154+α kVA	1,154+α kVA

Peak demand (kVA, A) of the feeder in a year?

6. Time Sequential Sectionalizer

WPSII, Avissawella, Seethawaka GSS, 33kV F01

All the conductor of Seetawaka F1 is Racoon ACSR of 46.83 km long.



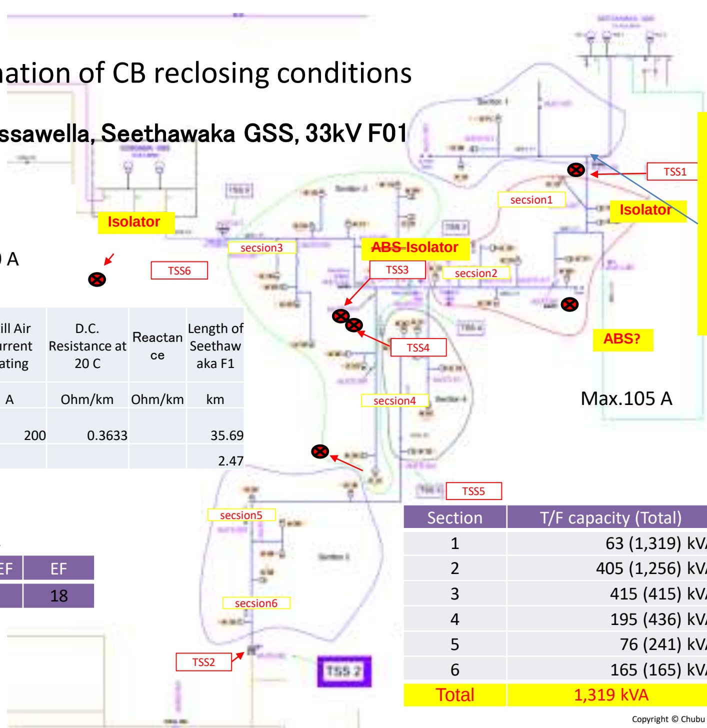
How counted? 1890 kVA as the total T/F capacity of Seethawaka F1?

OC	OC&EF	EF
33	125	18

Section	T/F capacity (Total)	Max demand
1	63 (1,319) kVA	1 (23) A
2	405 (1,256) kVA	7 (22) A
3	415 (415) kVA	7 (7) A
4	195 (436) kVA	3 (8) A
5	76 (241) kVA	1 (4) A
6	165 (165) kVA	3 (3) A
Total	1,319 kVA	23 A

Confirmation of CB reclosing conditions

WPSII, Avissawella, Seethawaka GSS, 33kV F01



CB reclose setting:
1 time in 1 sec in EF?
Open lock in case of re-trip?
No reclose in case of ? A or OC?
Please send the detail reclosing conditions!
Is it acceptable to set 2 times in every 60 sec in EF?

ACSR Code Word	Size		Still Air Current Rating	D.C. Resistance at 20 C	Reactance	Length of Seethawaka F1
	in.	mm	A	Ohm/km	Ohm/km	km
Racoon	7/.161	7/4.09	200	0.3633		35.69
Lynx						2.47

Fault number

OC	OC&EF	EF
33	125	18

Section	T/F capacity (Total)	Max demand
1	63 (1,319) kVA	1 (23) A
2	405 (1,256) kVA	7 (22) A
3	415 (415) kVA	7 (7) A
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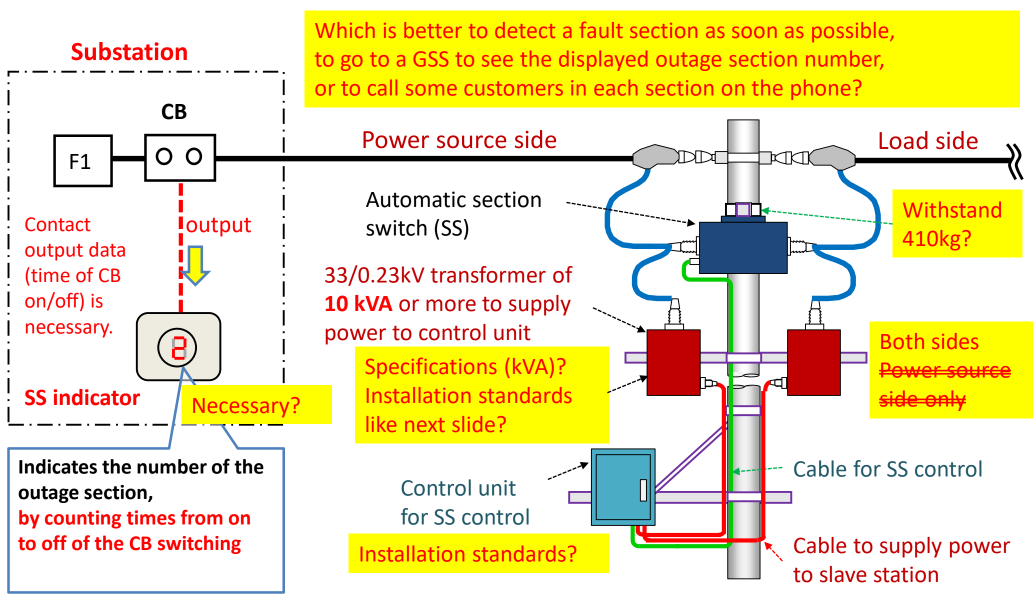
5	76 (241) kVA	1 (4) A
6	165 (165) kVA	3 (3) A
Total	1,319 kVA	23 A

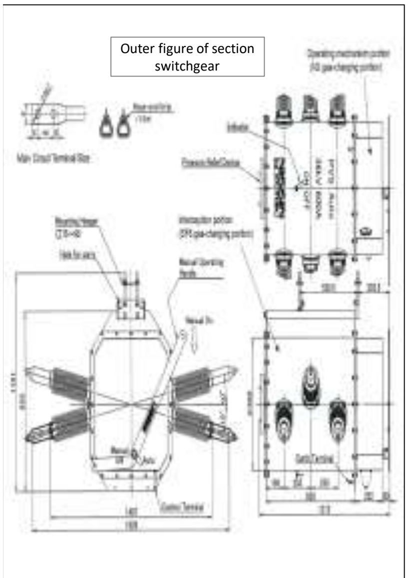
6. Time Sequential Sectionalizer

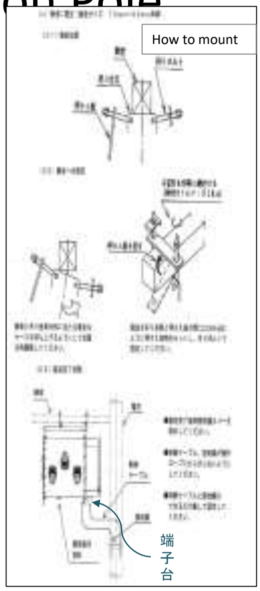
ID No.	Seetawaka GSS F1	46AVI-004	46AVA-003	46AVD-012	46AVD-044	46AVR-002	46AVA-005	46AVI-011	46HND-020	Others, Remarks
GPS coordinates (Latitude, Longitude)		6.965239672374695, 80.20266126848813	6.94004513908058, 80.19350404976622	6.938132827514306, 80.19421751736412	6.930081347694984, 80.18716261506891		6.954887534366224, 80.20446275331084	6.94290169211933, 80.14738169762816		one LBS sample data at any place
GPS coordinates (Latitude)	6.96821	6.96523479582891	6.94002169851056	6.93814959841156	6.93003173408916	6.87969317687901	6.95867831032996	6.94287082298143	6.86776697982974	
GPS coordinates (Longitude)	80.21030	80.2026586752899	80.1933732752882	80.1942142870403	80.1872324818375	80.1694051931943	80.2046724915444	80.1474389383310	80.1536919493270	
Present No. of Section Switch (TSS)	(CB)	TSS1	TSS2	TSS3	TSS4	(AR)	TSS2	TSS6	-	-
Proposed No. of the Section (Supplying order)	S1	S2	S3	S4	S5	S6	Reverse (S2)	Reverse (S3)	-	-
Name of existing facility	**CB**	**Isolator**	**ABS**	**DDLO**	**DDLO**	**AR**	**ABS**	**Isolator**	**DDLO**	**LBS**
Specificaitions of existing facility	(by other files)	-	(by other files)	-	-	(Received)	-	-	-	(Received)
Manufacturers of existing facility						BH SYSTEM Co.,Ltd	(Received)			(Received)
Type and Model number of existing facility										
With or without CT and/or VT	CT and VT	No	No	No	No	CT and VT	No	No	No	CT and VT
Photos (whole pole having switching facility)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)		(Unhasty)
Photos (only switching facility from different sides)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)	(Unhasty)		(Unhasty)
Rated current of existing facility (A)	200	-	400	-	-	400	400	-	-	400
Max. load current (peak demand) at 11:30 daytime (A)	21						105	70		Total T/F capacity.
Max. load current (peak demand) at 19:30 night (A)	23						59	70		
Total T/Fs capacity in all the downstream sections (A)	23	22	7	8	4	3	22	7		
Total T/Fs capacity in the first downstream section (kVA)	63	405	415	195	76	165				
Total T/Fs capacity in all the downstream sections (kVA)	1,319	1,256	415	436	241	165				
Name of the next feeder which can supply outage section reversely							Seethawaka F2	Kosgawa F4	Kosgawa F1	
Available supply capacity from the next feeders (kVA)							95 (200-105?)	130 (200-70?)		
Total T/Fs capacity in the first reverse section (kVA)							405	415		
Total T/Fs capacity in all the reverse sections (kVA)							1,256	415		
OC protection relay setting	1600 A - 100 ms delay					*** A - 4 cycles				
ditto	200 A - 120 T.M.S.									
EF protection relay setting	320 A - 100 ms delay					*** A - *** cycles				
ditto	40 A - 100 T.M.S.									
Circuit breaking (Opening) current and time (Condition 1)	*** A - *** ms					*** A - *** ms				
Circuit breaking (Opening) current and time (Condition 2)	*** A - *** ms					*** A - *** ms				
Reclosing number	*** times					*** times				
Reclosing setting	*** A - *** seconds					*** A - *** seconds				
No reclosing conditions	Over ***A					Over ***A				If any.
Reclosing (dead) time (second)	1, 2 or 5					from 0,5 to 120				Actual setting value
Lock-out in case of fault detection again	Yes					?				
Link to SCADA	ifix?					To be linked by 202*?				When? Common between transmission and distribution lines?
Link to communication network	Already linked?					By *** by 202*?				When? By optical fiber, public or dedicated wireless NW or?

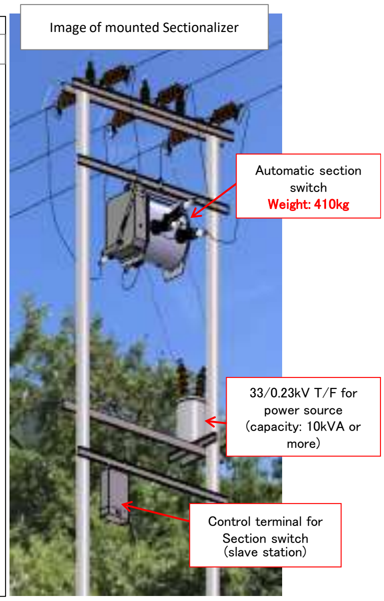
Confirmation regarding TSS



How to Mount TSS with Cross Arm on Pole



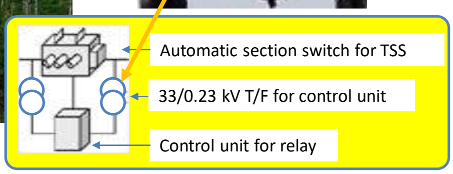


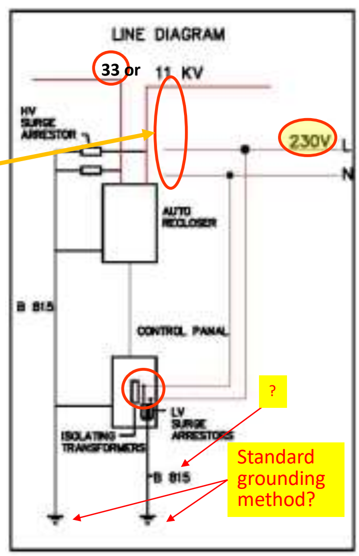


33/0.23 kV Transformer for TSS Control Unit

AR@46AVR-002

Specifications of the transformer(T/F)
33/0.23 kV
Single phase
Manufacturer name?
Type and specifications?





Isolator @46AVI-011 for TSS 6

Isolator @46AVI-004 for TSS 1

DDLO @46AVD-044 for TSS 5

DDLO @46AVD-020 for Reversely to AR

ABS @46AVA-003 for TSS 3

ABS @46AVA-005 for TSS 2

AR @46AVR-002 at DD Boundary

Power outage cause and countermasures

Countermeasures by fault classification (1/2)

Cause		Content	Countermeasures
Large category	Small category		
Inadequate facility	Incomplete production	Due to defects in the design, manufacturing, materials, etc. of electric works	revise the specification of materials, procure the design and planning models/softwares .Further, implementation of GIS programme.
	Incomplete construction	Due to workmanship defects in construction and repair work	strength the training for woking gangs and proper supervision
Inadequate maintenance	Incomplete maintenance	Due to imcomplete maintenance such as patrol, inspection, and repair	correct supervision and evalation of the work done as a closed loop.
		Due to the contact of trees within the range that the electric facility administrator should cut down	Increase the number of turns for clearing way leave depending of the severity of breakdowns. A case by case analysis couple with outage data. Correct supervision
	Natural deterioration	Due to the deterioration of the material and mechanism of the electrical facility, even though there were no particular defects in production, construction, and maintenance.	Identify such facilities in advanced and introduce stringent maintenance programme.
	Overload	Due to overcurrent exceeding the rated capacity	optimise the devices based on planning limitations.(Ex: load the conductors less than 70% of the thermal rating. Transformers between 60-70%)
Natural phenomenon	Wind and rain	Due to rain, wind or storm including contact with tree fragment by wind	adjust the way leave clearing programmes according to the rainy seasons. Set up disaster management plans ready to curtail the failure duration.
	Ice and snow	Due to snow, ice, hail, hail, sleet or storm snow	N/A
	Lightning	Due to direct lightning strike	Installation of surge arrestors properly.
		Due to induced lightning	placement of reclosers and coordinate properly.
	Earthquake	Due to the earthquake	N/A
	Flood damage	Due to flood, storm surge, tsunami, etc.	keep disaster management plan ready
	Landslide and avalanche	Due to landslides, avalanches, subsidence, etc.	avoid such areas as much as possible after being identified by relevant departments.
	Salt, dust and gas	Due to salt, dust, fog, malignant gas, soot, etc.	wash the line insulators periodically. Use the polymer type insulators for lines prone to salt deposits.

Countermeasures by fault classification (2/2)

Cause: Large category	Cause: Small category	Content	Countermeasures
Intention/negligence	Worker's fault	Due to the negligence of the worker	Train the workers on safety measures and on good workmanship.
	Public intention/negligence	Due to the intention or negligence of the public (meaning persons other than workers) such as stone throwing, wire theft, and suicide	work with law enforcement agencies to punish such persons. Use of placards giving warnings in identified areas.
	Felling without permission	When the public fells trees that are close to electric facilities, they fell without permission and contacting the facility's administrator, which impaired the function of electric facilities.	execute the law agaist such behaviours and impose penalty charge
	Fire	Due to fires in houses close to electric facilities, forest fires, and other types of burning	educate customers and coordinate with relevant fire departments.
Contact with other objects	Contact with trees	Due to contact or approach by the inclination or collapse of trees.	remove them with the contact of relevant parties.
	Contact with birds and beasts	Due to contact with cats, mice, snakes or birds, nesting, etc.	coordinate the reclosers properly with other breaker in the uptream switching devices
	Other	Due to contact with a kite, radiosonde, advertising balloon, model airplane, hot air balloon, etc.	coordinate the reclosers properly with other breaker in the uptream switching devices
Corrosion	Electrical corrosion	Due to corrosion by leakage current from DC type electric railway	N/A
	Chemical corrosion	Due to corrosion by chemical action	periodic maintenance.
Vibration	Vibration	Due to vibration of heavy vehicles, foundation work, etc.	avoid such works from public places as much as possible
Other accident spread	Own comoany	Due to the spread of accidents of other electric facilities of the own company	follow proper planning procedures
	other company	Due to the spread of accidents of electric facilities other than our own company	cordinate with such companies and come to an agreement
Poor fuel	Poor fuel	Due to the use of fuel with a composition significantly different from the design fuel	
Other	Other	Items not classified in any of the "Causes"	N/A
Unkown	Unkown	The cause is not clear even after investigation.	

Activities for improving SAIDI

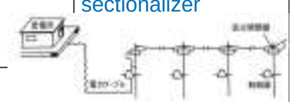
Classification of measures to improve supply reliability in our company

			Countermeasures
Power failure countermeasures	Measures for early power recovery [related to SAIDI]	Automation of power restoration to sections without failure	Automatic fault section detection system with time sequential sectionalizer
		Narrow down the patrol area	Overcurrent indicator
			Fault section locator
			Ground fault detector
			Manual switch (instantaneous closing operation) etc.
	Failure reduction measures [related to SAIFI]	Induced lightning (several tens of kV to several hundred kV)	Insulation coordination by insulators, Lightning horn, Lightning cutout
		Direct lightning strike (several hundred kV to several thousand kV or more)	Lightning arrestor, Overhead ground wire
		Contact with other objects such as birds, snakes, and trees	Enclosed cutout Bird/snake protection cover Transformer bushing cover
		Negligence (vehicle collision, construction crane contact, etc.) Propagation of other accidents (failure of high-voltage receiving facilities, etc.)	Branch line breaker, etc.
		Insufficient facilities Inadequate maintenance	Inspection synchronized with construction

In order to improve the supply reliability, there is also a reduction in construction blackouts.

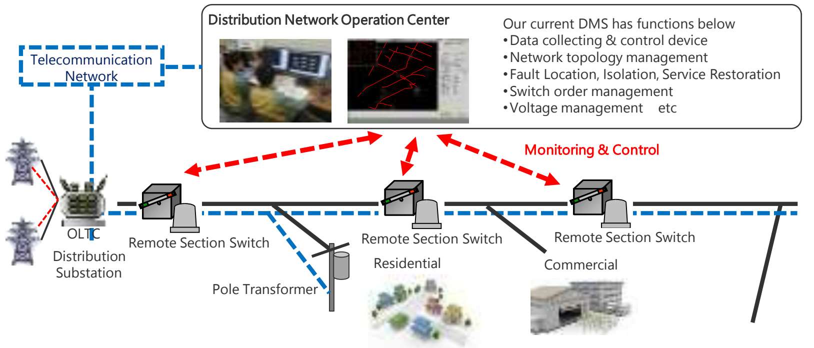
WG3:Power Failure Countermeasures

Countermeasures for power failure reduction and early restoration

Failure cause	Trend	Approach	SAIFI measures	SAIDI measures
Touch (Tree, bird, etc.)	Trends of area and season, Areal rise	Patrol, Each approach, Low cost	Enclosed cutout, conductor cover, etc.	Automatic fault detection system with time sequential sectionalizer
Customer ripple affection, Error (car crash, etc.)	Local rise, Low trend	Awareness rise, Protection, Patrol	Breaker of customer	
Facility defect, Maintenance defect	Trends by each type of facility	Measures based on spec. and areal trend	Inspection with other on-site work	Fault indicator
Induction strike (dozens kV - hundreds kV)	Trends of area and season. Rise in wide area	Wide area, Possible measures	Insulator coordination, arching horn, etc.	
Direct strike (hundreds kV - thousands kV or more)	Trends of area and season. Low frequency	Huge cost, Difficult measures	Lightning rod	Ground fault detector 
Nature phenomenon (excluding strike, typhoon, earthquake, tsunami, heavy rain, etc.)	Low frequency, Rise in wide area, Trends of area and season	Wide area, Huge cost, Difficult measures	Higher specification design	Over current indicator, Manual switch, etc.

01 Outline of CEPCO’s Distribution Grid Operation

- Current Distribution Management System (DMS) aids work efficiency and swift power supply switching, by controlling Remote Section Switchs, for construction/maintenance works and isolating faults during breakdowns.
- Especially, our FLISR has been contributing to keep safety and reliability of our electricity networks.
- SAIFI is almost less than 0.1times and SAIDI is almost less than 5minutes except for disaster.



Insulation resistance measurement (megger measurement) against ground fault

The power failure section is divided into two, and the worker climbs up to measure the insulation resistance value of the high-voltage distribution equipment using an insulation resistance measuring instrument.

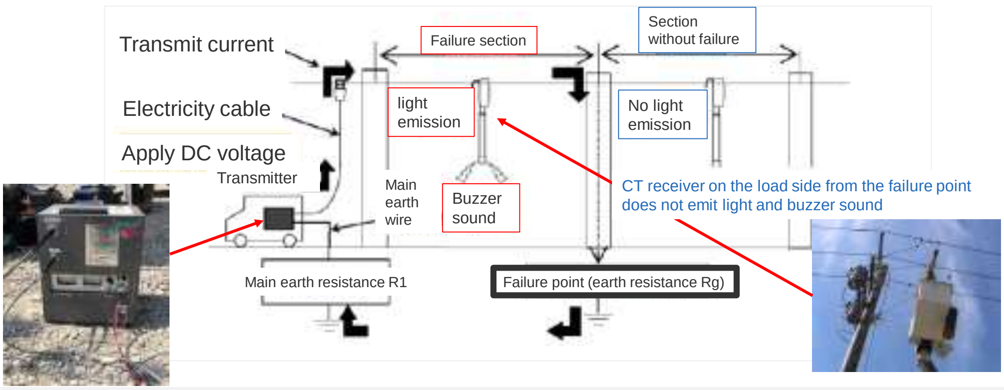
The cause is specified by the measured value "0 MΩ".

Measurement work on the pole

Insulation resistance measuring instrument

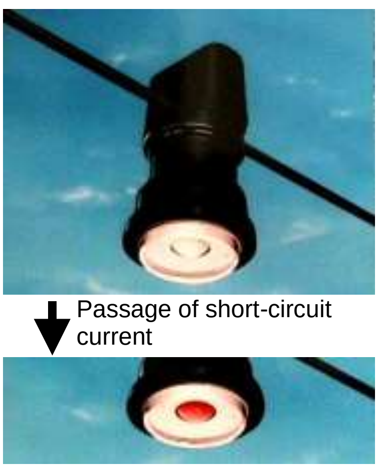
Ground fault detector

DC voltage (5 to 15 kV) is applied to the high voltage line in the power failure section by the fault detector, and the ground fault current is received.
The cause of the failure is identified by the light emission and buzzer sound of the receiver.

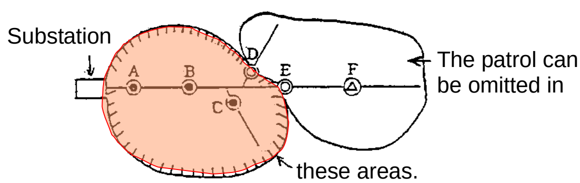


Over Current Indicator (OCI) and patrol areas

To efficiently make patrols



Indication changes of OC (by electricity)



The patrol should be performed in these areas.
Over current indicator legend

- ◉ Color change (A, B, C)
- ◎ White (D, E)
- △ No need of checking (F)

Figure 9: Over Current Indicator(OCI) and patrol areas

Calculation of effect of reducing power outage time

A model of shortening power outage time by introducing Ground fault detector
*The breakdown of power failure time is tentative
If the breakdown is not currently recorded, the shortened time is calculated assuming the time for each process.

■ Before [Unit: min]

Outage duration	(breakdown)			
	Going to the site	Fault investigation	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
120	20	60	10	30

-30min (-25%)

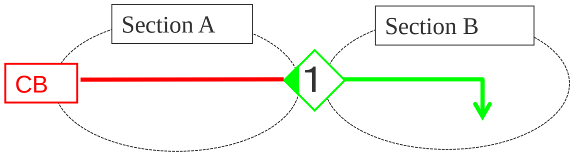
■ After [Unit: min]

Outage duration	(breakdown)			
	Going to the site	Fault investigation	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
90	20	30	10	30

From this result, it is possible to predict how much power outage time can be reduced in the selected feeder. This leads to the setting of target values for PDM.

Calculation of saved outage

A model of saved outage [kWh] by introducing time sequential sectionalizer.

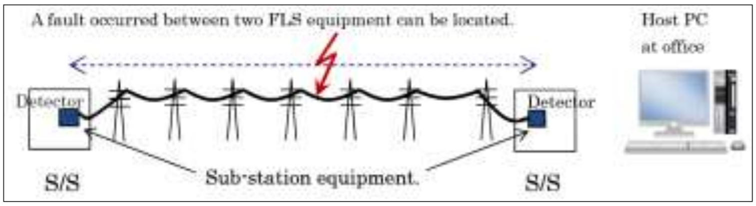


Date	Day	Detection time	Recovery time	Outage duraton time	Estimated values of load side of Switchgear, just before a fault occurs (A+B)						Estimtated total values of the feeder, just before a fault occurs (B)						Power source side of Switchgear (A)		
					R	Y	B	Average	Outage		R	Y	B	Average	Total		Saved outage		
					[A]	[A]	[A]	[A]	[kW]	[kWh]	[A]	[A]	[A]	[A]	[kW]	[kWh]	[A]	[kW]	[kWh]
8/15/2018	Wed	5:15	5:35	0:20	52	54	56	54	926	306	130	135	140	135	2,315	764	81	1,389	458
8/19/2018	Sun	11:30	11:55	0:25	48	50	54	51	875	368	120	126	134	127	2,178	915	76	1,303	547
		:	:	:				**0**	**0**					**0**	**0**		**0**	**0**	
		:	:	:				**0**	**0**					**0**	**0**		**0**	**0**	
		:	:	:				**0**	**0**					**0**	**0**		**0**	**0**	

From this result, it is possible to predict how much power outage [kWh] can be reduced in the selected feeder.

Fault Locating System (FLS) (1/2)

1. Overview of FLS
- Locates and indicates faults on transmission and distribution lines;
- Consists of fault detectors installed at substations and Host PC placed at a regional maintenance & service office;
- Capable of detecting faults occurred on the line that has a detector at either end.



2. Advantage

FLS reduces losses from outages and the overall cost of line maintenance.

-Accurate Locating

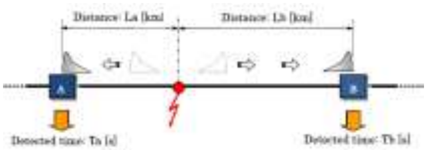
-Efficient Fault Locating Work = Fast Service Restoration & Personnel Cost Saving

-Detection of Various Fault Types

Fault Locating System (FLS) (2/2)

3. Detection principle

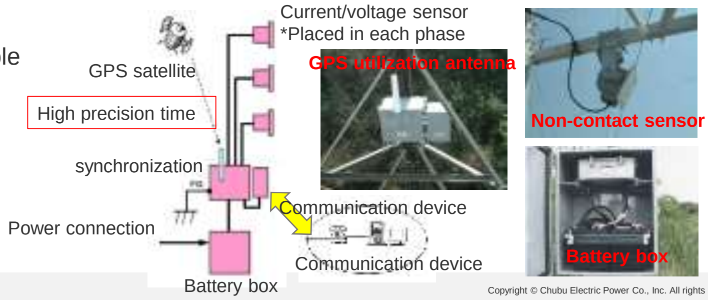
When a failure occurs in the area sandwiched by two or more devices, the progress waveform is detected with accurate time synchronization and the position is located.



$$La = \frac{1}{2}(L + (Ta - Tb) \times V) \quad [m]$$

L: Distance between the FLS device (between A and B) (L=La+Lb) [m]
V: Propagation speed of surge signal [m/s]
Ta: Time when the surge of the locator A is detected
Tb: Time when the surge of the locator B is detected

4. Configuration example



Conductor Cover for Way Leaves

item	Performance
Commercial frequency withstand voltage	Drying: 15kV x 1 minute, Watering: 10kV x 1 minute
Abrasion resistance	Outer layer 1000 times, Inner layer 500 times
Flame retardant performance	V-0 class

Reference URL: https://www.fujikura.co.jp/products/infrastructure/otherproduct/01/2044039_11376.html

4. Enclosed Cutout Fuse

[Overview]

The cutout is installed on the primary side of the transformer in order to separate the distribution transformer from the distribution line. The enclosed cutout is constructed with the fuse holder concealed by insulators. This can prevent equipment failure due to contact with flying debris and salt damage.

Rating

-Rated Voltage	:	12kV
-Rated Current	:	50A
-Rated Frequency	:	50 / 60Hz
-Fuse Link Amperage	:	6A - 50A (max)
-Ambient Temperature	:	-20°C ~ +40°C
-Altitude	:	< 1000m
-Operation Cycle (at no load)	:	> 500 times
-Increase Temperature	:	60°C
-Rated Interrupting Current	:	12.5kA, 3times
-Load Break	:	50A / 15 times,65A / 5 times
-Power-frequency Withstand Voltage	:	42kV (to earth and between pole)
	:	48kV (Across isolating distance)
-BIL (Basic Impulse Level)	:	75kV (to earth and between pole)
	:	85kV (Across isolating distance)
-Interrupting Capacity (Sym Current)	:	12.5kA
-Creepage Distance	:	280mm (25mm/ kVx11.2)
-Weight	:	4.2kg

[Request]

To connect the cutout to the equipment, please send us construction drawings and photos of the transformer primary.

CHUBU Electric Power
NIPPON KOEI

Activities for improving SAIFI

Classification of measures to improve supply reliability in our company

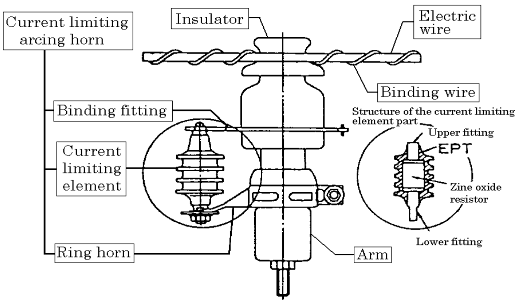
CHUBU Electric Power
NIPPON KOEI

			Countermeasures
Power failure countermeasures	Measures for early power recovery [related to SAIDI]	Automation of power restoration to sections without failure	Automatic fault section detection system with time sequential sectionalizer
		Narrow down the patrol area	Overcurrent indicator
			Fault section locator
			Earth fault detector
			Manual switch (instantaneous closing operation) etc.
	Failure reduction measures [related to SAIFI]	Induced lightning (several tens of kV to several hundred kV)	Insulation coordination by insulators, Lightning horn, Lightning cutout
		Direct lightning strike (several hundred kV to several thousand kV or more)	Lightning arrestor, Overhead ground wire
		Contact with other objects such as birds, snakes, and trees	Enclosed cutout Bird/snake protection cover Transformer bushing cover
		Negligence (vehicle collision, construction crane contact, etc.) Propagation of other accidents (failure of high-voltage receiving facilities, etc.)	Branch line breaker, etc.
		Insufficient facilities Inadequate maintenance	Inspection synchronized with construction

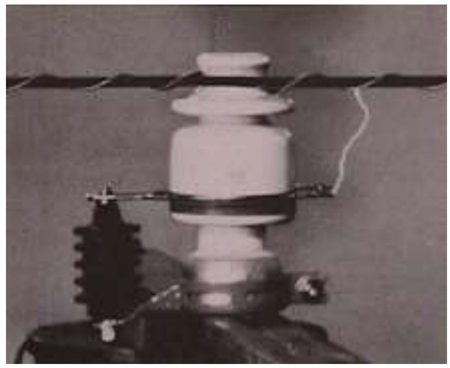
In order to improve the supply reliability, there is also a reduction in construction blackouts.

Lightning horn

Prevention a lighting-cause conductor burndown



Shutting off the continuous current flowing

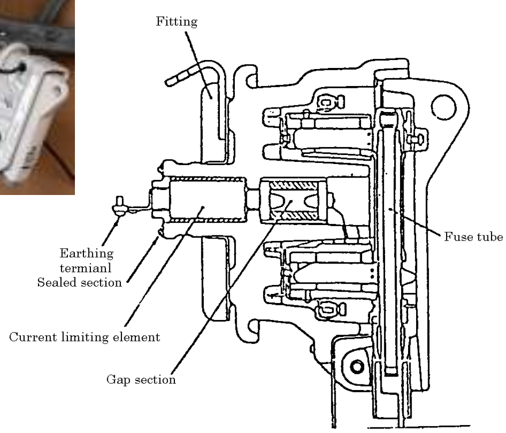


Lightning Protection Primary Cutout Switch

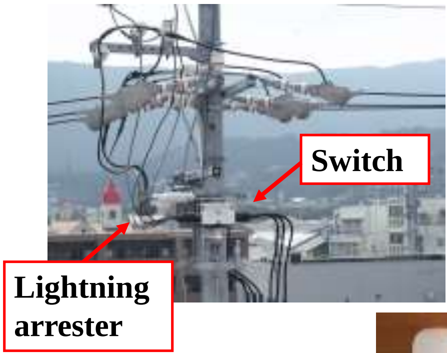
Prevention against faults in transformers

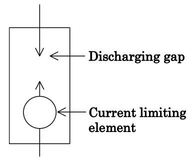
Composition of a discharge gap and a current limiting element (ZnO)

Structural diagram of Lightning Protection PC Switch

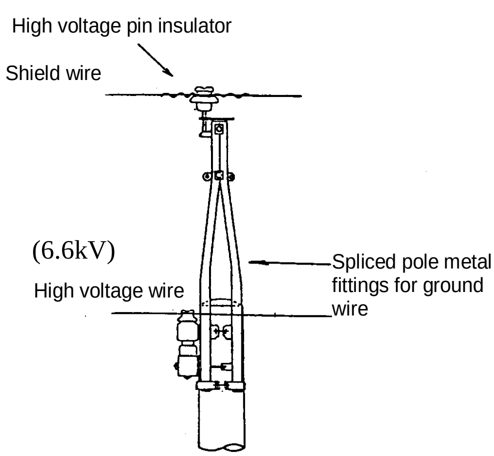


Lightning arrester





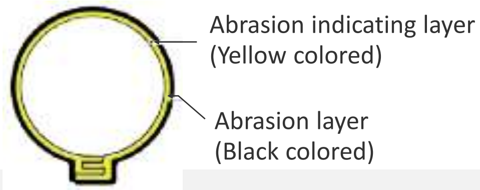
Shield wire



Protection for high voltage wires

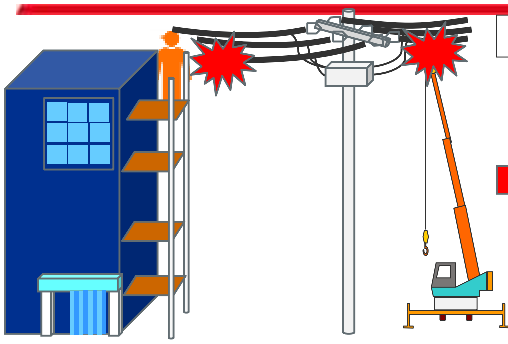
Control of the lightning induced effect

Abrasion Resistance Cover for Wire



As abrasion has been progressed, the "Abrasion indicating layer" appears. This situation shows that this cover should be replaced.

Cover for wire at construction site



to prevent

Install cover

Cover is removed after construction

We certainly appeal to worker for risk of shock on site

Keep the public safe

Wire Connecter

PJ (Parallel Joint) connector

no work failure, long lifetime, no overheat and less loss

Torque cap for appropriate torque

Introduction of PJ connector also leads to reduce non-technical loss.

Failure analysis method

Power outage status by failure cause/damaged facility

Damaged facility \ cause			Inadequate equipment		Inadequate maintenance			Natural phenomenon							Intentional/negligence			Contact with other objects			Other accident spread						
			Incomplete production	Incomplete construction	Incomplete maintenance	Natural deterioration	Overload	Wind and rain	Ice and snow	Thunder	earthquake	Flood damage	Landslides and avalanches	Salt, dust, gas	Worker's fault	Public willfulness/negligence	logging	Contact with trees	Contact with birds and beasts	Other	In-house	Other company	fire	Other	unknown	total	percentage(%)
Overhead line	Electric pole	Steel tower																									
		concrete pole				1		22	1				4		1	25	1	5								60	3.7
		steel pole						14	1				1				2	2								20	1.2
		wooden pole																									
	cross arm					1		21	4							1		3								30	1.9
	insulator				1	2		5								1	1	1								11	0.7
	Electrical wire			5	38	36		448	33	18			8		1	13	15	148	11	5	1	3	6	4	1	794	49.4
	transformer				6	4		6		18					1				4	21				1		61	3.8
	Switches	switch		1	7	14		9	1	4						1		4	9	6				9		65	4.0
		disconnector																									
		insulator－TYPE SWITCH			1	6		1		6														1		15	0.9
	power capacitor																										
	lightning arrester					1				10									1	1				2		15	0.9
	etcetera					3		11	1	1						1	1	2		1			1			22	1.4
	No damage			1	31	11	2	121	7	8		1	3		13	8	1	25	58	36			5	14	169	514	32.0
	subtotal			7	84	79	2	658	48	65		1	16		16	50	21	190	83	70	1	3	12	31	170	1,607	100.0
	percentage（%）			0.4	5.2	4.9	0.1	40.9	3.0	4.0		0.1	1.0		1.0	3.1	1.3	11.8	5.2	4.4	0.1	0.2	0.7	1.9	10.6	100.0	
Underground line	cable					2										1								2		5	45.5
	joint box																										
	cable head					2														1						3	27.3
	etcetera															2								1		3	27.3
	subtotal					4										3				1				3		11	100.0
	percentage（%）					36.4										27.3				9.1				27.3		100.0	
sum total				7	84	83	2	658	48	65		1	16		16	53	21	190	83	71	1	3	12	34	170	1,618	

Utilization of power failure data

Classifying by area is useful for understanding regional characteristics

Province/Areas \ cause			Inadequate equipment		Inadequate maintenance			Natural phenomenon							Intentional/negligence			Contact with other objects			Other accident spread					
			Incomplete production	Incomplete construction	Incomplete maintenance	Natural deterioration	Overload	Wind and rain	Ice and snow	Thunder	earthquake	Flood damage	Landslides and avalanches	Salt, dust, gas	Worker's fault	Public willfulness/negligence	logging	Contact with trees	Contact with birds and beasts	Other	In-house	Other company	fire	Other	unknown	total
DD1	Nothern	N1 Jaffna																								
		N2 Kilinochchi																								
		N3 Vavuniya																								
	North Central	NC1 Anuradhapura																								
		NC2 Kekirawa																								
		NC3 Minneriya																								
	North Western	NW1 Chilaw																								
		NW2 urunegala																								
total																										

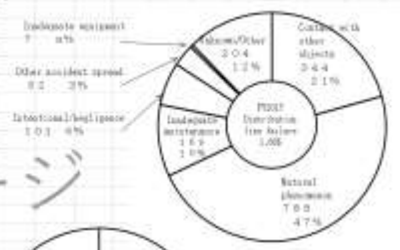
Analysis of power outages by cause of failure and damaged equipment

(1)High voltage distribution line failure (Blackout)

a The number of failures in 2017 was 1,695.

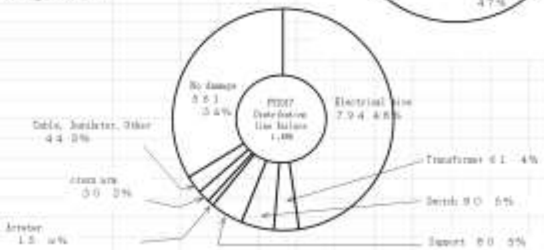
b The breakdown by cause of failure is as follows.
Natural phenomena (thunder, wind, rain, snow damage, etc.) account for the majority, accounting for approximately 47%.
Others account for about 21%, and maintenance deficiencies and equipment deficiencies account for about 10%.

	Blackout	
	number	ratio (%)
Contact with other objects	344 (Contact with birds and beasts [illegible])	21
Natural phenomenon	788 (Thunder [illegible])	47
Inadequate maintenance	169 (Natural deterioration [illegible])	10
Intentional/negligence	101 (Car crash 34)	6
Other accident spread	82	5
Inadequate equipment	7	*
Unknown/Other	204	12
total	1,695	100



c The breakdown of the damaged equipment is as follows, with no damage accounting for about 34%.

	Blackout	
	number	ratio (%)
Electrical wire	794	48
Transformer	61	4
Switch	80	5
Support	80	5
arrester	15	*
cross arm	30	2
insulator	11	*
Cable	5	*
Other	28	1
No damage	561	34
計	[illegible]	100

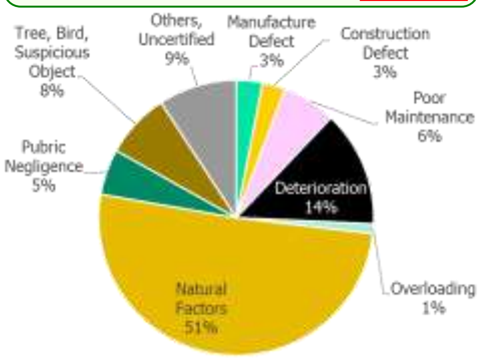


Transformer abnormality cases in Japan

➢ Pole Transformer **abnormality cases leading to power outage** in all over Japan in FY 2018

$$\frac{\text{Abnormality case}}{\text{Total amount in Japan}} = \frac{\text{507 cases}}{\text{10.7 million}}$$

↳ **0.005%**



Cause of outage	Number
Manufacture Defect	16
Construction Defect	14
Poor Maintenance	33
Deterioration	71
Overloading	6
Natural Factors (Rainfall, lightning, Snow, etc.)	265
Public Negligence	14
Tree, Bird, suspicious object	40
Others, Uncertified	48
Sum total	**507**

Source : Electrical security statistics, Ministry of Economy, Trade and Industry in Japan, March 2020
https://www.meti.go.jp/policy/safety_security/industrial_safety/sangyo/electric/detail/denkihoantoukei.html

Analysis and sharing of failure cause and failure mechanism

After confirming the faulty equipment by patrol, investigate the cause and mechanism of the fault.
As a result of the investigation, if necessary, we will work with manufacturers to improve equipment and develop countermeasures.
These experiences are accumulated and shared in the in-house document system so that similar events do not occur.

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Example of sharing failure cause and failure mechanism

Contact with trees, Nesting, Contact with other objects

Defective content

Overview

Feature

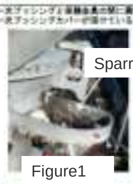


Figure1

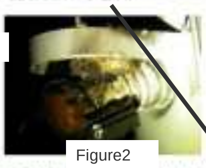


Figure2

mechanism

1. Foreign matter in the gap between the primary bushing and the primary bushing protective fitting.
2. Leakage current occurs between the primary bushing charging part and the primary bushing protective fitting
3. Carbonized conductive path is formed on the surface of the primary bushing
4. Occurrence of ground fault, burning of cover, etc.

Measures for new products

Ready-made measures: None

upport for removed products: None

Reference material: National Research Institute of Police Science (Tracking phenomenon of organic insulators and fire)

Dielectric breakdown

Trees and foreign matter (such as nesting) enter the gap between the handle insulators of the primary bushing and contact the live parts.
Even if it is not in direct contact with the charging part, only by contacting the primary bushing cover, leakage current continues to flow in the insulating cover and the insulating cover tracks.

・A foreign substance (bird, beast, fruit, etc.) is placed between the primary bushing and the protective fitting (Figs. 1 and 2).
・The primary bushing cover is melted (Fig. 2)

If birds and beasts intrude into the gap between the transformer primary bushing and the primary bushing protective fitting, or drop foreign matter (fruits, etc.) into the gap, leakage current will flow through the foreign matter and cause a ground fault in rainy weather. (Figs. 1, 2)

・Install the primary bushing protection bracket cover
・Uses a transformer without a primary bushing protection bracket cover

Install the primary bushing protection bracket cover

appearance

Installation state

Mounting method

Attach the cover guide to the transformer's protective metal fittings.

Push straight

Insert it until it clicks, and rock the cover back and forth to make sure that it does not come off the protective metal fittings.

Calculation of effect of reducing power outage frequency(SAIFI)

A model of shortening power outage time by introducing Fault section locator
*Tentative time is set for breakdown of power outage
If the breakdown is not currently recorded, the shortened time is calculated assuming the time for each process.

(Before) Unit: times

Outage frequency	Remarks
10	Assumed that measures have been taken for about half of the target feeders

-5times (-50%)

(After) Unit: times

Outage frequency	Remarks
5	Assumed that measures have been taken for about half of the target feeders

From this result, it is possible to predict how much power outage frequency can be reduced in the selected feeder.

Calculation of effect of reducing power outage time(SAIDI)

A model of shortening power outage time by introducing Ground fault detector
*The breakdown of power failure time is tentative
If the breakdown is not currently recorded, the shortened time is calculated assuming the time for each process.

■ Before [Unit: min]

Outage duration	(breakdown)			
	Going to the site	Fault investigation	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
120	20	60	10	30

-30min (-25%)

■ After [Unit: min]

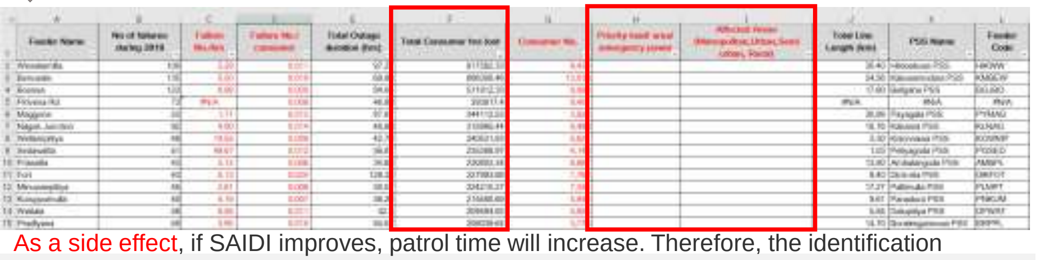
Outage duration	(breakdown)			
	Going to the site	Fault investigation	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
90	20	30	10	30

From this result, it is possible to predict how much power outage time can be reduced in the selected feeder. This leads to the setting of target values for PDM.

Prioritization and selection of countermeasure areas considering the improvement of SAIDI related to pilot project

Power outage data from LECO

-Sort by "Total Consumer hours lost (row F)" to confirm the effect of SAIDI improvement
-Furthermore, consider the factors of "Priority load/ area/ emergency (row H)" and "Affected areas (Metropolitan, Urban, Semi urban, Rual) (row I)"
-Prioritize the countermeasure feeder after considering other necessary factors.

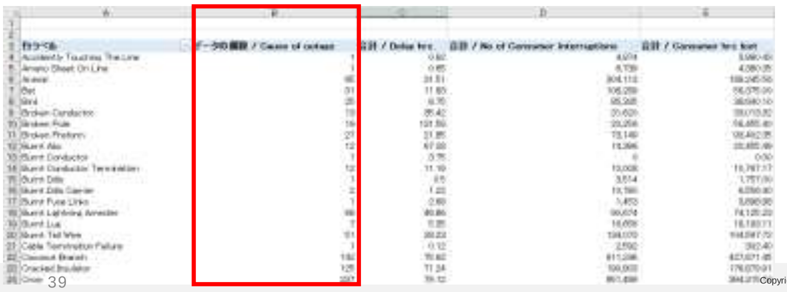


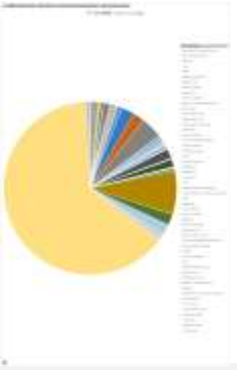
As a side effect, if SAIDI improves, patrol time will increase. Therefore, the identification of the cause of failure will increase, leading to improvement of SAIFI.

Prioritization and selection of countermeasure areas considering the improvement of SAIFI related to pilot project

Raw power outage data from LECO

Organize data by “the Number of cause of outage (row B)” to confirm the effect of SAIFI improvement





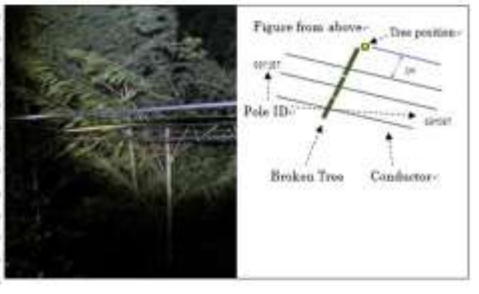
Record of power outage summary.

＜Outage Report (The First Draft to Discuss)＞

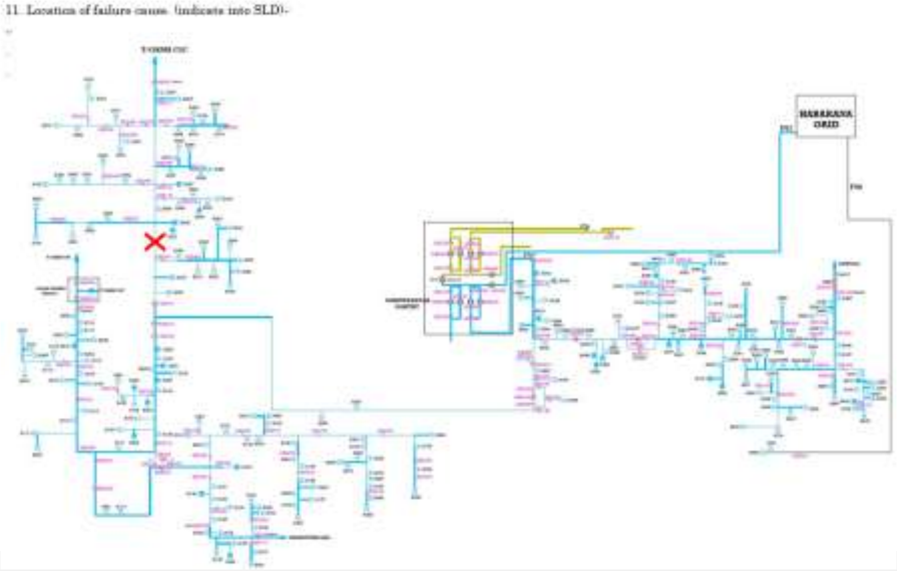
1. Date / Weather : 9th, July, 2021 / Rainy
2. Office : XXXXX
   Province / District : NCP / Anuradhapura
3. Substation / Feeder : Habarana / 07
4. Power failure detection : ☑OC ☐EF ☐OC-EF
5. Outage duration(Maximum) : 180 minutes
6. Number of customer (Maximum) : 4,567 customers
7. Progress of Restore

	Time	Number of Restored Customer	Remarks
Power outage	16:30	−	
Partial recovery1	17:00	1,567	
Partial recovery2	17:30	1,400	
Partial recovery3	17:45	1,200	
Partial recovery4	18:00	300	
Partial recovery5	−	−	
Partial recovery6	−	−	
Full recovery	19:30	100	

8. Category of power outage : A09
   Detail Of A28 :
9. Damaged Part : conductor
10. Failure Cause in detail
    A broken tree touched conductors



Record of power outage summary.

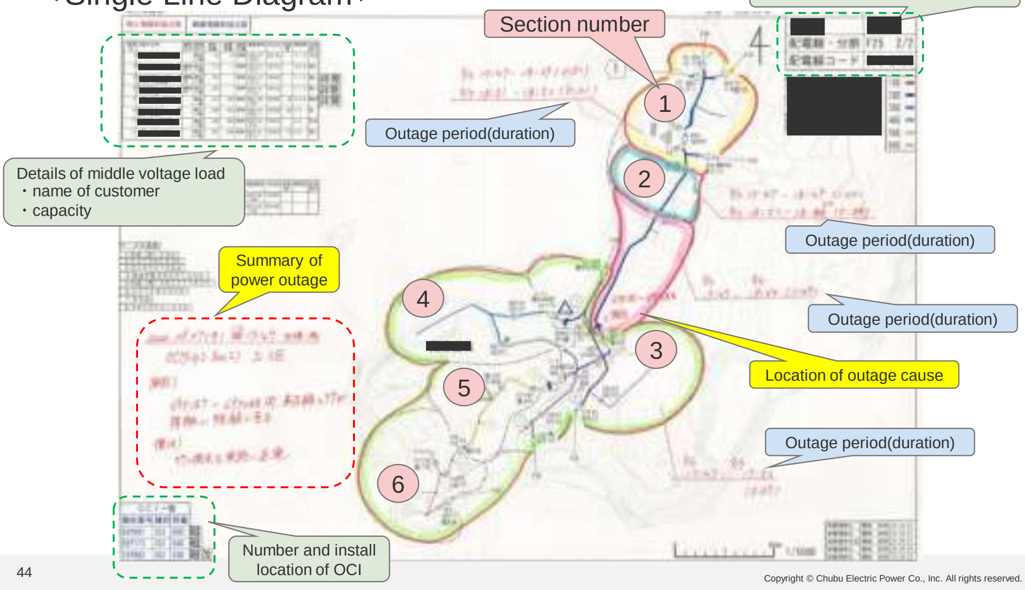


Record of power outage summary.

＜Outage Report (draft)＞

Details of failure record (CHUBU Electric Power)

＜Single Line Diagram＞



Calculation method of SAIDI and SAIFI

SAIDI and SAIFI of Sri Lanka in 2018,2017

〇SAIFI： System Average Interruption Frequency Index

SAIFI is one of main index to show how many times blackout occurred per one year, per one consumer.

SAIFI in Sri Lanka (Source CEB information)

Organization	SAIFI [number]
DD1	15.1 (2018)
DD2	43.8 (2018)
DD3	56.8 (2018)
DD4	36.2 (2018)
LECO	109 (2017)

$$\text{SAIFI} = \frac{\text{Total number of power outage in a year}}{\text{Total number of consumer of organization}}$$

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SAIDI and SAIFI of Sri Lanka in 2018,2017

〇SAIDI (System Average Interruption Duration Index)

SAIDI is main index to show how long duration blackout occurred per one year, per one consumer.

SAIDI in Sri Lanka (Source CEB information)

Organization	SAIDI [seconds]	[min]
DD1	4,532 (2018)	75.5
DD2	4,468 (2018)	74.5
DD3	4,885 (2018)	81.4
DD4	5,911 (2018)	98.5
LECO	4,196 (2017)	69.9

$$\text{SAIDI} = \frac{\text{Total power outage duration in a year}}{\text{Total number of consumer of organization}}$$

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Determine the target value of PDM

To determine the target value of PDM, calculate SAIDI and SAIFI based on the 2019 power outage record.

Indicator	Current Status	Target value of PDM
(6) SAIFI at the pilot sites where the facilities against power outage are installed. ・Abrasion Resistance Cover for Conductor ・Enclosed Cutout Fuse	at 2019 XX in DD1(cover) XX in DD1(cutout) XX in DD4(cover) XX in DD4(cutout) XX in LECO(cover) XX in LECO(cutout)	at 2023 XX in DD1(cover) XX in DD1(cutout) XX in DD4(cover) XX in DD4(cutout) XX in LECO(cover) XX in LECO(cutout)
SAIDI at the pilot sites where the facilities against power outage are installed. ・Over current Indicator ・Ground Fault Detector	at 2019 XX in DD1(OCI1) XX in DD1(OCI2) XX in DD1(OCI3) XX in DD1(GFD1) XX in DD1(GFD2) XX in DD1(GFD3) ・ XX in DD1(GFDn) ・・・DD2-4,LECO	at 2023 XX in DD1(OCI1) XX in DD1(OCI2) XX in DD1(OCI3) XX in DD1(GFD1) XX in DD1(GFD2) XX in DD1(GFD3) ・ XX in DD1(GFDn) ・・・DD2-4,LECO

calculate before 15.March 2021

determine before April 2021(tentative)

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Calculation of effect of reducing power outage time(SAIDI)

Ground Fault Detector

	Responsibility C/P	Province /District	Substation / Feeder name (11kV,33kV)	Annual fault number OC	both	EF
DD1	H.I.S Jayasundara	NWP /Puttlam	Norochcholai /F02 (Palakuda to Kalpitiya)	2	0	14
DD2	Mrs.S.Gowrithasan	Eastern /Batticaloa	Valaichchenai GSS to Eravur / F06	15	0	0
DD3	D.M.D. Ranawaka	Uva /Badulla	Mahiyanganaya GSS/ F3(Adaulpotha)	9	4	141
DD4	W. C. H. Dhanapala	WPSI /Colombo	Rathmalana GSS/ F2			
LECO	Sampath Dissanayaka	Southern /Galle	Hikkaduwa PSS - /F Wewalamilla (Galle branch area)	5	0	94
			Gonapinuwala PSS			
			Dick-ela PSS			
			Beligaha PSS			
			Ambalangoda PSS			

①Please list the all Substation /Feeder name where apply GFD.

②Please find the outage data of each feeder.

Estimation of Equipment Introduction Effect

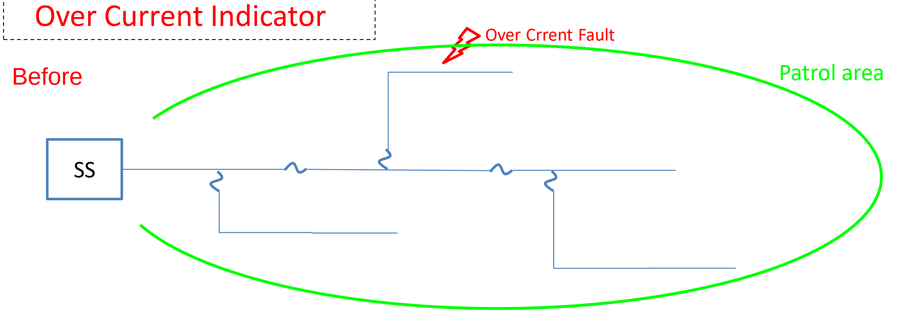
Countermeasure Equipment for SAIDE & SAIFI

Countermeasure Equipment	SAIDI (System Average Interruption Duration Index)	SAIFI (System Average Interruption Frequency Index)
Overcurrent Indicator	✔	—
Ground Fault Detector	✔	—
Abrasion Resistance Cover for Conductor	—	✓

Calculation of effect of reducing power outage time(SAIDI)

＜case1＞
Over Current Indicator

Before

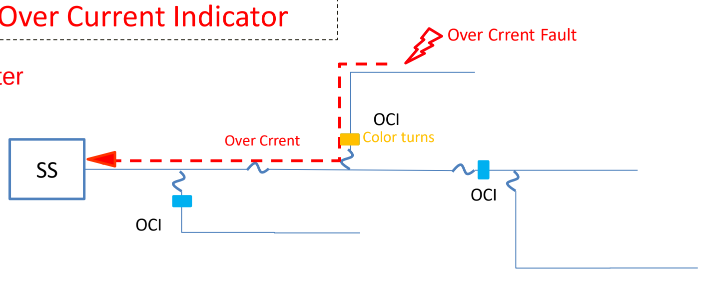


Outage duration	(breakdown)			
	Going to the site	Fault investigation（Patrol:Repost）	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
260	20	180(180)	30	30

Calculation of effect of reducing power outage time(SAIDI)

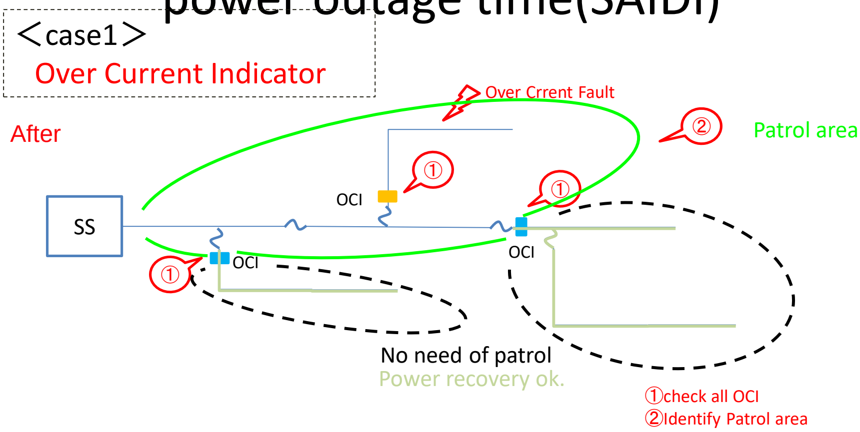
＜case1＞
Over Current Indicator

After

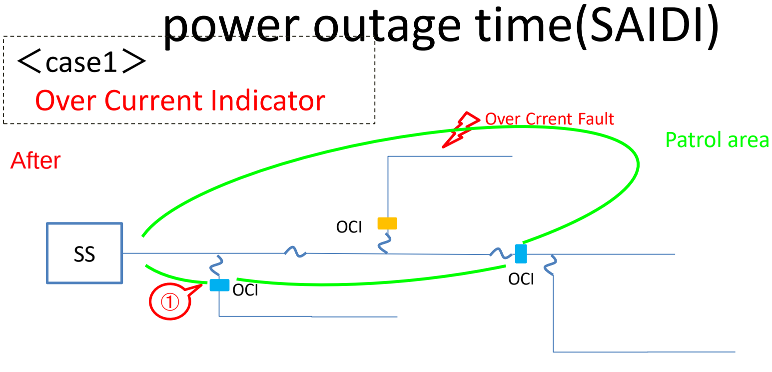


OCI

Calculation of effect of reducing power outage time(SAIDI)



Calculation of effect of reducing power outage time(SAIDI)



	Outage duration	(breakdown)[min]			
		Going to the site	Fault investigation（Patrol:Repost）	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
Before	260	20	180(180)	30	30
	-100min		-80min(-90)	-20min	
After	160	20	100(90)	10	30

Calculation of effect of reducing power outage time(SAIDI)

＜case1＞ Over Current Indicator

Annual effect of ***each Feeders***

※total consumer of a feeder = 500,000(tentative)

Before

date	A:Outage duration[min]	B:Consumer No	A×B [min]	Failulre Aspect
1/5	360	1,000	360,000	OC
3/17	300	3,000	900,000	EF
5/15	400	8,000	3,200,000	EF
6/24	700	4,000	2,800,000	OC
7/1	400	13,000	5,200,000	OC
7/12	420	7,000	2,940,000	EF
9/30	210	4,000	840,000	OC
10/8	180	11,000	1,980,000	EF
12/9	240	5,000	1,200,000	EF
Total	-	-	**19,420,000**	-

After

date	A:Outage duration[min]	B:Consumer No	A×B [min]	Failulre Aspect
1/5	150	1,000	150,000	OC
3/17	300	3,000	900,000	EF
5/15	400	8,000	3,200,000	EF
6/24	300	4,000	1,200,000	OC
7/1	170	13,000	2,210,000	OC
7/12	420	7,000	2,940,000	EF
9/30	110	4,000	440,000	OC
10/8	180	11,000	1,980,000	EF
12/9	240	5,000	1,200,000	EF
Total	-	-	**14,220,000**	-

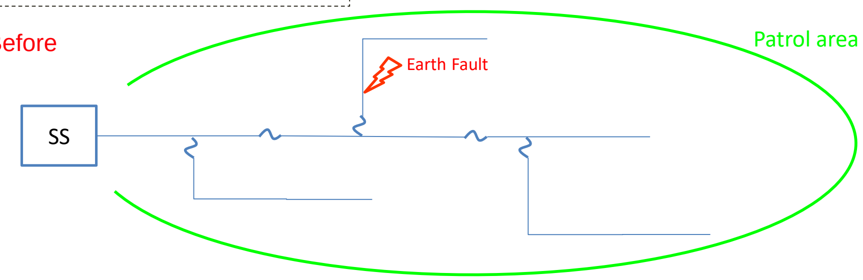
SAIDI **38.84**※ [min/consumer ,year] ➡ **28.44**※ [min/consumer ,year]

=19,420,000 / 500,000 =14,220,000 / 500,000

Calculation of effect of reducing power outage time(SAIDI)

＜case2＞ Ground Fault Detector

Before

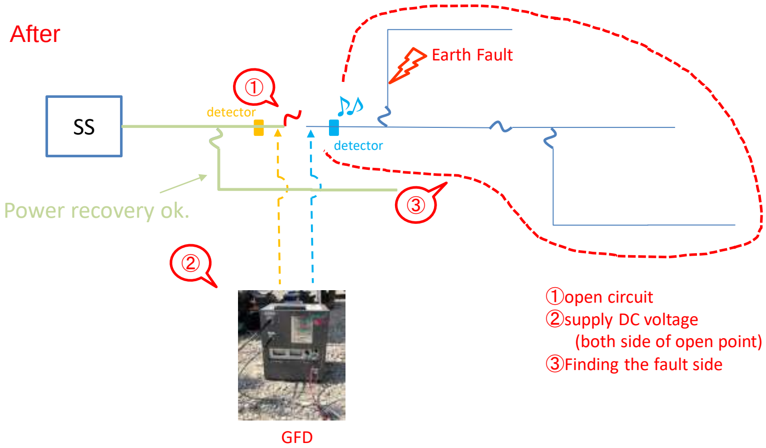


Outage duration	(breakdown)			
	Going to the site	Fault investigation (Patrol:Repost)	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
260	20	180(180)	30	30

Calculation of effect of reducing power outage time(SAIDI)

＜case2＞
Ground Fault Detector

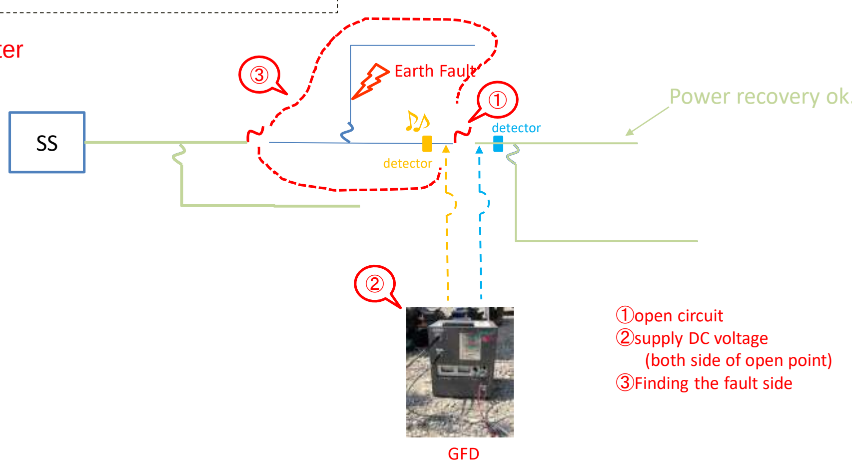
After



Calculation of effect of reducing power outage time(SAIDI)

＜case2＞
Ground Fault Detector

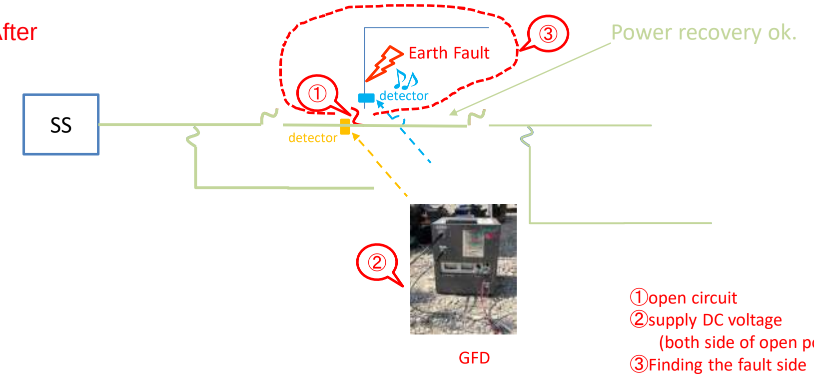
After



Calculation of effect of reducing power outage time(SAIDI)

＜case2＞
Ground Fault Detector

After



①open circuit
②supply DC voltage
(both side of open point)
③Finding the fault side

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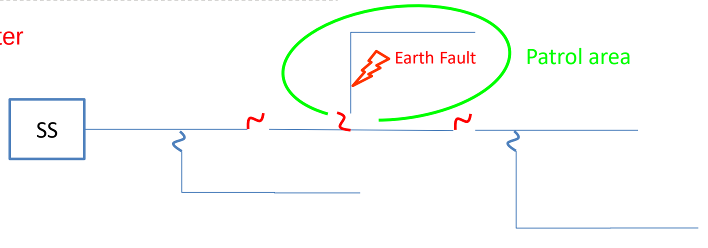
Calculation of effect of reducing power outage time(SAIDI)

＜case2＞
Ground Fault Detector

After



	Outage duration	(breakdown)[min]			
		Going to the site	Fault investigation (Patrol:Repost)	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
Before	260	20	180(180)	30	30
	-140min		-120min(-150)	-20min	
After	120	20	60(30)	10	30

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Calculation of effect of reducing power outage time(SAIDI)

＜case2＞ Ground Fault Detector

Annual effect of each ***Feeder***

※total consumer of District = 500,000(tentative)

Before

date	A:Outage duration[min]	B:Consumer No	A×B [min]	Failulre Aspect
1/5	360	1,000	360,000	OC
3/17	300	3,000	900,000	EF
5/15	400	8,000	3,200,000	EF
6/24	700	4,000	2,800,000	OC
7/1	400	13,000	5,200,000	OC
7/12	420	7,000	2,940,000	EF
9/30	210	4,000	840,000	OC
10/8	180	11,000	1,980,000	EF
12/9	240	5,000	1,200,000	EF
Total	-	-	19,420,000	-

After

date	A:Outage duration[min]	B:Consumer No	A×B [min]	Failulre Aspect
1/5	360	1,000	360,000	OC
3/17	160	3,000	480,000	EF
5/15	180	8,000	1,440,000	EF
6/24	700	4,000	2,800,000	OC
7/1	400	13,000	5,200,000	OC
7/12	300	7,000	2,100,000	EF
9/30	210	4,000	840,000	OC
10/8	60	11,000	660,000	EF
12/9	200	5,000	1,000,000	EF
Total	-	-	14,880,000	-

SAIDI **38.84**※ [min/consumer ,year] → **29.76**※ [min/consumer ,year]

=19,420,000 / 500,000 =14,880,000 / 500,000

Calculation of effect of reducing power outage time(SAIDI)

SAIDI

・Based on the recent performance of each process, we calculate the shorten time due to introducing each countermeasure.

※(The breakdown of power failure time in the table below is a tentative)

・If there is no record of the breakdown, the shorten time is calculated assuming the time of each process.

[Unit: min]

	Outage duration	(breakdown)			
		Going to the site	Fault investigation (Patrol:Repost)	Power recovery outside the faulty section	Cause identification/Power recovery for all sections
Before	260	20	180(180)	30	30
	-120min		-120min(-150)		
After	140	20	60(30)	30	30

From this result, it is possible to predict how much power outage time can be reduced in the selected feeder. This leads to the setting of target values for PDM.

PDM
・OCI：SAIDI of the each feeders .(3 Feeders where OCI will be installed.)
・GFD：SAIDI of the each feeders.(All Feeders in District where GFD will be apllied.)

Calculation of effect of reducing power outage frequency(SAIFI)

＜case3＞
- Abrasion Resistance Cover for Conductor
- Enclosed Cutout Fuse

	number of outage	(cause) Lightning	Trees and Branches	Animals and birds	Other accident spread	Vehicle accident	Unknown /other
Before	300	20	100	30	15	5	130
	-120		-70	-10			-40
After	180	20	30	20	15	5	90

Calculation of effect of reducing power outage frequency(SAIFI)

＜case3＞
- Abrasion Resistance Cover for Conductor
- Enclosed Cutout Fuse

Annual effect of each ***Feeder***

※total consumer of District = 500,000(tentative)

Before

Cause	Number of outage
Lightning	300,000
Tree and Branches	1,320,000
Animals and birds	900,000
Oher accident spread	250,000
Vehicle accident	182,000
Unknown/other	4,130,000
Total	**7,082,000**

After

Cause	Number of outage
Lightning	300,000
Tree and Branches	580,000
Animals and birds	550,000
Oher accident spread	250,000
Vehicle accident	182,000
Unknown/other	3,300,000
Total	**5,162,000**

SAIFI 14.16※ [times/consumer ,year] → **10.32**※ [min/consumer ,year]

=7,082,000 / 500,000 =5,162,000 / 500,000

Calculation of effect of reducing power outage time(SAIDI)

SAIFI

・Based on the recent record of power outage number by cause, we calculate the decreased frequency due to introducing each countermeasure.
※(The breakdown of the cause of power outage in the table below is a tentative)

・If there is no record of the breakdown, the decreased frequency is calculated assuming the frequency of each cause.

[Unit: times]

	number of outage	(cause) Lightning	Trees and Branches	Animals and birds	Other accident spread	Vehicle accident	Unknown /other
Before	300	20	100	30	15	5	130
	-120		-70	-10			-40
After	180	20	30	20	15	5	90

From this result, it is possible to predict how much power outage frequency can be reduced in the selected feeder. This leads to the setting of target values for PDM.

PDM
・Cover , Cutout：SAIFI of the each feeder .
(A Feeder where Cover or Cutout will be installed.)

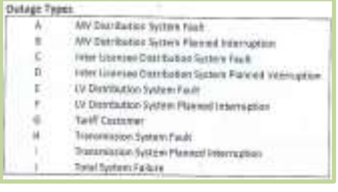
Details of failure record (draft)

Details of power failure record required to evaluate Pilot project.(draft)

Date (time)	Province	District	Sub station	Feeder	Total Consumer (C:Σ(cn))	Outage Duration1 (d1)(time)	Consumer Number1 (c1)

Outage Duration2 (d2) (time)	Consumer Number2 (c2)	Outage Duration3 (d3) (time)	Consumer Number3 (c3)	・・・	Total Outage duration (D:Σ(dn × cn))

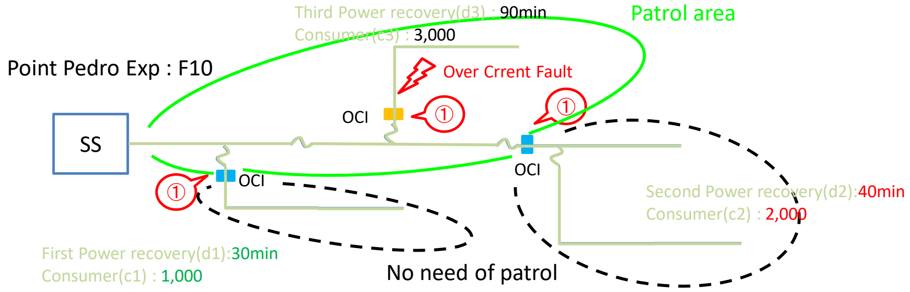
Failure aspect	Outage ypes	Cause of outage	・・・	・・・	・・・
OC/EF	A~J	A01~A28			


Outage Types

A	MV Distribution System Fault
B	MV Distribution System Planned Interruption
C	Inter Licensed Distribution System Fault
D	Inter Licensed Distribution System Planned Interruption
E	LV Distribution System Fault
F	LV Distribution System Planned Interruption
G	Tariff Customer
H	Transmission System Fault
I	Transmission System Planned Interruption
J	Total System Failure

Details of failure record (draft)

Date (time)	Province	District	Sub station	Feeder	Total Consumer (C:Σ(cn))	Outage Duration1 (d1)	Consumer Number1 (c1)	Outage Duration2 (d2)	Consumer Number2 (c2)	Outage Duration3 (d3)	Consumer Number3 (c3)	・・・	Total Outage duration (D:Σ(dn × cn))	Failure Aspect
2/10 (10:00)	North	Jaffna	PointPedroExp	F10	5,000	30 (10:30)	1,000	40 (10:40)	2,000	90 (11:30)	3,000		380,000	OC



3. Estimation of the effect of introducing OCI

Example （DD1:OCI-1 ：Habarana F07）

Patrol duration[min/failure]

Patrol duration
100

Number of power failure[/year]

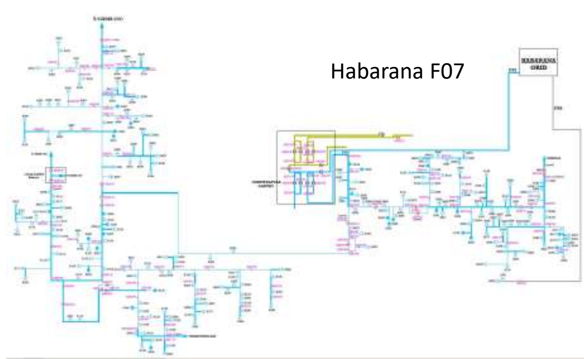
	OC	EF	OC·EF	total
2019	31	49	92	172
%	18.0	28.5	53.5	100

Total patrol duration (2019)

172 × 100=**17,200** [min/year]

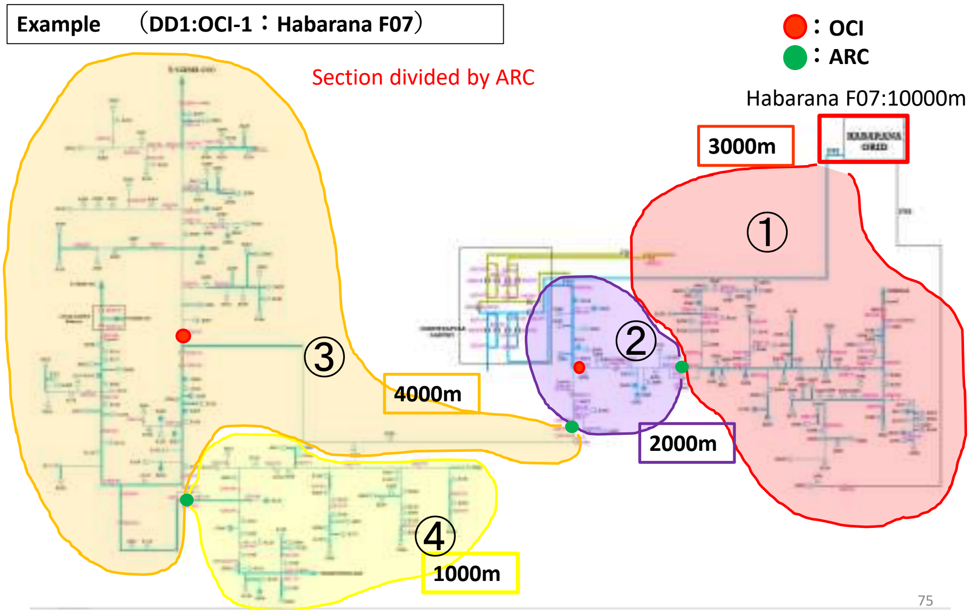
18.0 + 53.5 = **71.5%**

Ⅰ : Effective in 71.5% of power failure.



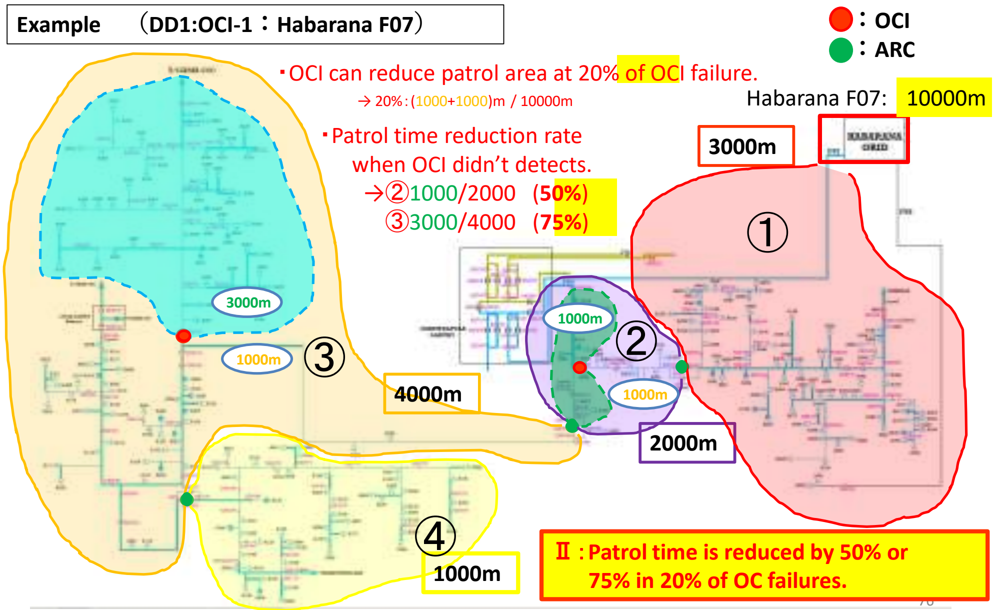
3. Estimation of the effect of introducing OCI

Example （DD1:OCI-1：Habarana F07）



3. Estimation of the effect of introducing OCI

Example （DD1:OCI-1：Habarana F07）



3. Estimation of the effect of introducing OCI

Example （DD1:OCI-1：Habarana F07）

Before(2019)

Number of power failure

2019	OC	EF	OC･EF	total
	31	49	92	172
%	18.0	28.5	53.5	100

18.0+53.5=71.5%

Patrol duration[min / failure]

Patrol duration
100

Total patrol duration [min/year]

172 × 100 = **17,200**

After(Estimation)

Ⅰ : Effective in 71.5% of power failure. (OC failure)

Ⅱ : Patrol time is reduced by 50% or 75% in 20% of OC failures.

Total patrol duration [min/year]

OC : (172 × 71.5% × 10%) × (100min × 50%)
＋(172 × 71.5% × 10%) × (100min × 25%)
＋(172 × 71.5% × 80%) × 100min
=10,761 min/year

EF : (172 × 28.5%) × 100mins = 4,900 min/year

Total patrol duration [min/year]

= 15,661

△9.0%

3. PDM：OCI

Example （DD1:OCI-1：Habarana F07）

✔ The reduction rate of total patrol duration is regarded as the reduction rate of total power outage duration.

Before(2019)

SAIDI (min)
80

△9%

After(Estimation)

SAIDI (min)
72.8

PDM

3. Estimation of the effect of introducing ARC

Example （DD4:ARC(cover)：Matara(Rahula) F01&2）

Number of power failure

2019	OC	EF	OC･EF	total
	14	17	2	33

data included F2?
or only F1?

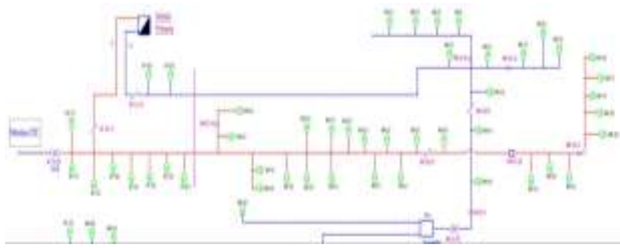
Number of tree/etc contact

2019	Tree/etc contact
	6

6 / 33 = **18%**

Ⅰ：Effective in 18% of power failure.

Matara(Rahula) F01&02



3. Estimation of the effect of introducing ARC

Example （**DD4:ARC(cover)**：**Matara(Rahula) F01&2**）

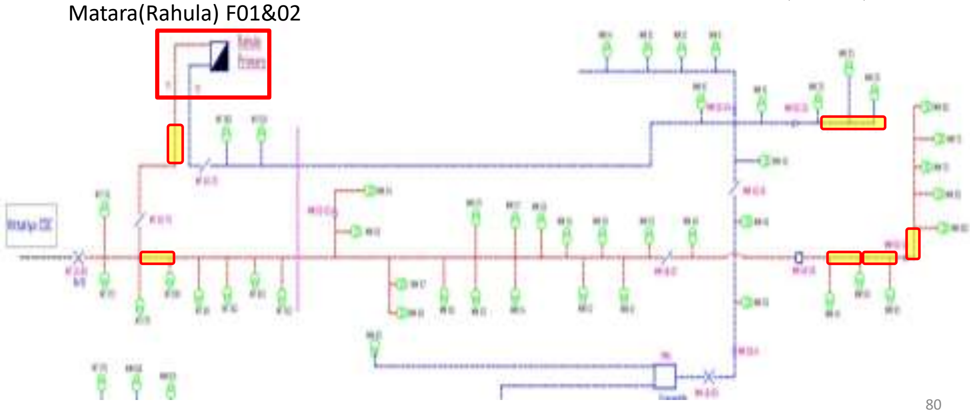
･ARCC(cover) will be installed at all tree contact points.

Ⅱ：No more tree contact

※Suppose all tree contact is occurring in the conductor.

：ARCC (Total 162m)

Matara(Rahula) F01&02



3. Estimation of the effect of introducing ARC

Example （**DD4:ARC(cover)：Matara(Rahula) F01&2**）

Before(2019)

Number of power failure

	OC	EF	OC･EF	total
2019	14	17	2	33

Number of tree/etc contact

	Tree/etc contact
2019	6

Total number of power failure

33 [/year]

After(Estimation)

6 / 33 = **18%**

Ⅰ：Effective in 18% of power failure.
Ⅱ：No more tree contact

Total number of power failure

33 - 6 = 27 [/year]

Total number of power failure

27 [/year]

△18%

81

3. PDM：ARC

Example （**DD4:ARC(cover)：Matara(Rahula) F01&2**）

✔ The reduction rate of total number of power failure is regarded as the reduction rate of power outage frequency.

Before(2019)

SAIFI
36

△18%

After(Estimation)

SAIFI
30

PDM

82

3. Estimation of the effect of introducing Cutout

Example （**DD4:Cutout**：**Matara(Rahula) F04**）

Number of power failure

	OC	EF	OC･EF	total
2019	6	1	20	27

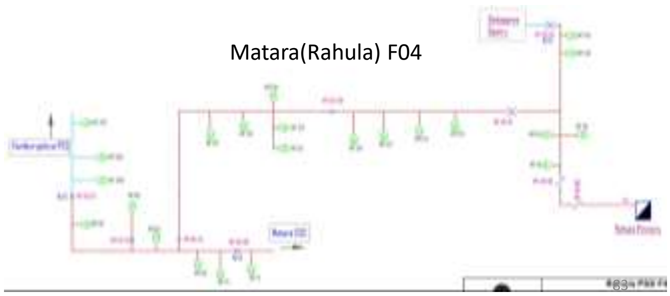
Number of tree/etc contact

	Tree/etc contact
2019	18

18 / 27 = 66%

Ⅰ：Effective in 66% of power failure.

Matara(Rahula) F04



3. Estimation of the effect of introducing Cutout

Example （**DD4:Cutout**：**Matara(Rahula) F04**）

total number of transformer	Number of transformers with cutouts installed
19	6

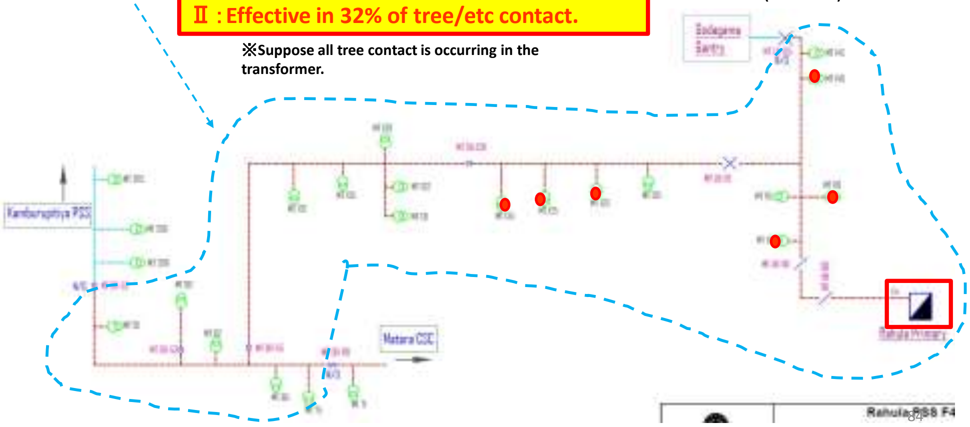
6 / 19 = 32%

Ⅱ：Effective in 32% of tree/etc contact.

※Suppose all tree contact is occurring in the transformer.

● **: Cutout**

Matara(Rahula) F04



3. Estimation of the effect of introducing Cutout

Example （DD4:Cutout：Matara(Rahula) F04）

Before(2019)

Number of power failure

	OC	EF	OC･EF	total
2019	6	1	20	27

Number of tree/etc contact

	Tree/etc contact
2019	18

total number of transformer	Number of transformers with cutouts installed
19	6

Total number of power failure

27 [/year]

After(Estimation)

Ⅰ：Effective in 66% of power failure.
Ⅱ：Effective in 32% of tree/etc contact.

Number of tree/etc contact

18 × (100% - 32%) = 12 [/year]

Total number of power failure

27 - (18 - 12) = 21 [/year]

Total number of power failure

21 [/year]

△22%

3. PDM：Cutout

Example （DD4:Cutout：Matara(Rahula) F04）

✔ The reduction rate of total number of power failure is regarded as the reduction rate of power outage frequency.

Before(2019)

SAIFI
36

△22% →

After(Estimation)

SAIFI
28

PDM

3. Estimation of the effect of introducing GFD

Example （**DD2:GFD**：**Valaichchenai F06**）

Number of power failure

	OC	EF	OC･EF	total
2019	3	20	1	24

20 / 24 = 83%

Ⅰ：Effective in 83% of power failure.

Patrol duration[min / failure]

Patrol duration
100

⇒

Patrol duration[min / failure]

Patrol duration
50

Ⅱ：Patrol time for EF failures is reduced by 50%.

※Assume that it will be reduced to 50% for some reason.

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3. Estimation of the effect of introducing GFD

Example （**DD2:GFD**：**Valaichchenai F06**）

Before(2019)

Number of power failure

	OC	EF	OC･EF	total
2019	3	20	1	24

Patrol duration[min / failure]

Patrol duration
100

Total patrol duration [min/year]

24 × 100 = 2,400

After(Estimation)

Ⅰ：Effective in 83% of power failure.
(EF Failure)
Ⅱ：Patrol time for EF failures is reduced by 50%.

Total patrol duration [min/year]

EF：(24 × 83%) × (100min × 50%)
=1,000 min/year
OC：(24 × 17%) × 100mins = 400 min/year

Total patrol duration [min/year]

= 1,400

△42%

88

3. PDM：GFD

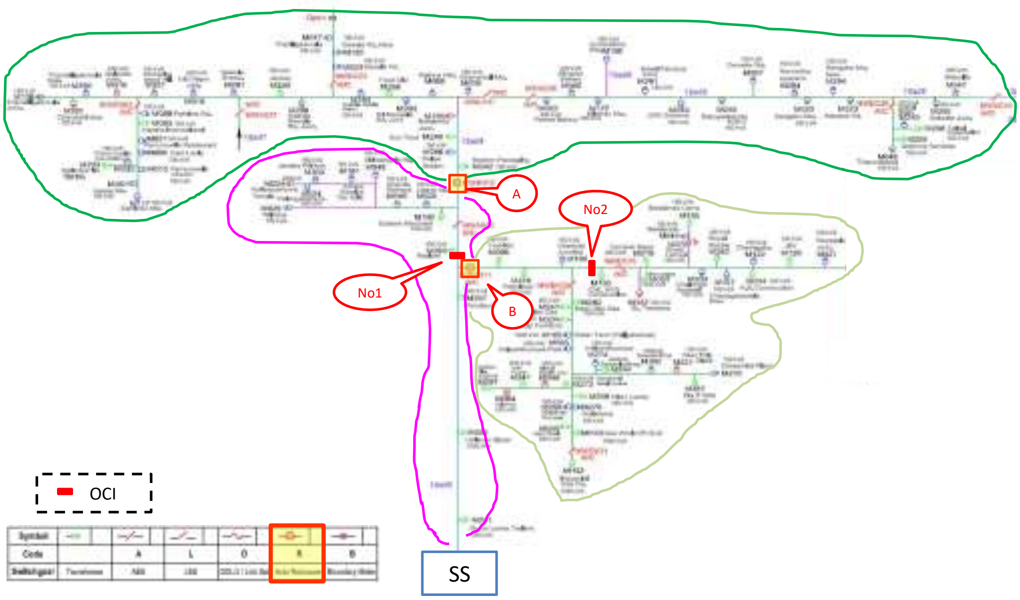
Example （**DD2:GFD：Valaichchenai F06**）

✔ The reduction rate of total patrol duration is regarded as the reduction rate of total power outage duration.

Before(2019)		After(Estimation)
SAIDI	**△42%**	**SAIDI**
75	➡	**44**

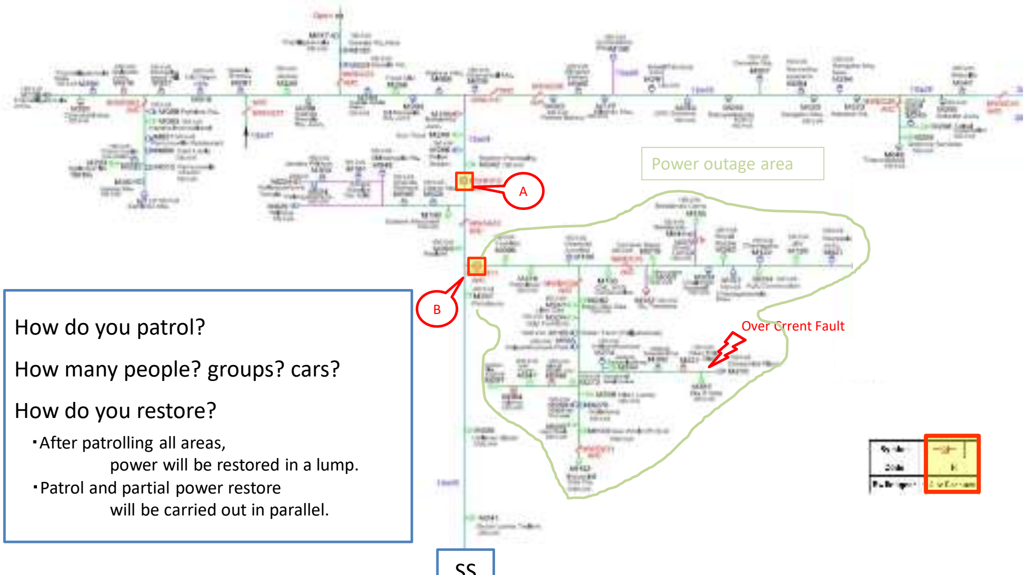
PDM

Details of failure record (draft)



Sapugaskanda/F09(DD2)

Patrol of outage area.



How do you patrol?

How many people? groups? cars?

How do you restore?

・After patrolling all areas,
power will be restored in a lump.

・Patrol and partial power restore
will be carried out in parallel.

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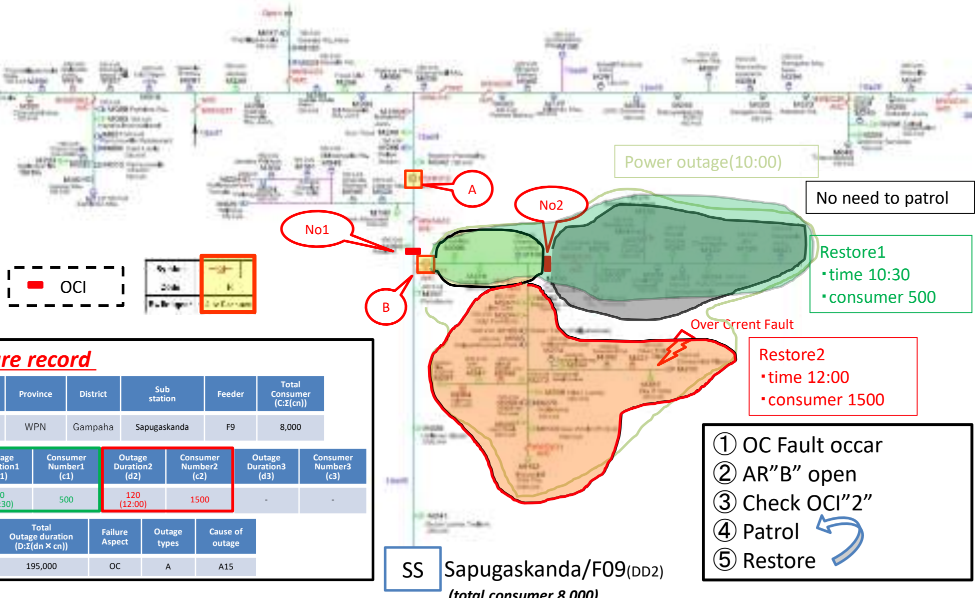
Details of failure record (draft)



failure record

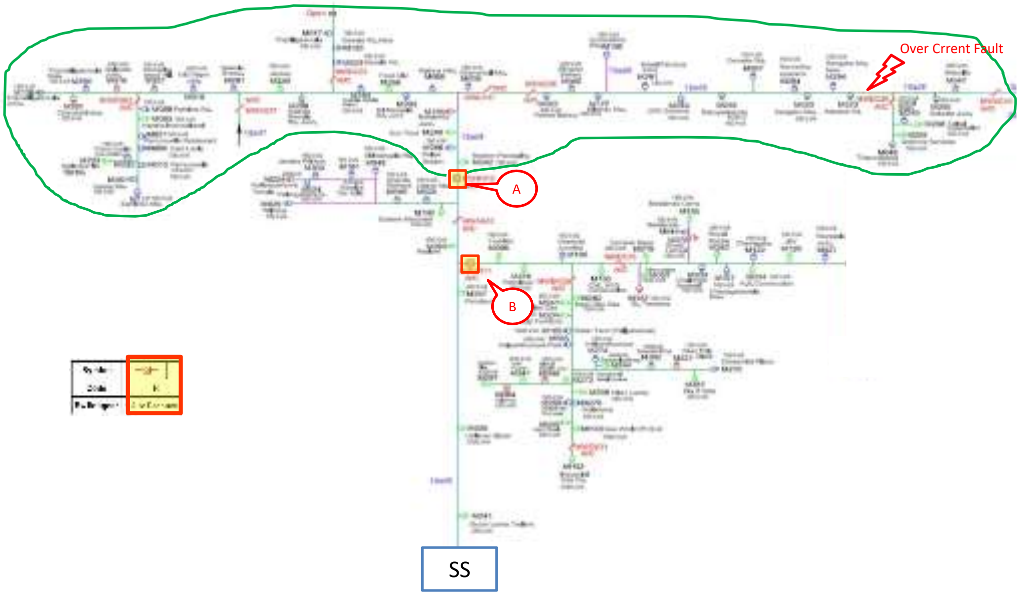
Date (time)	Province	District	Sub station	Feeder	Total Consumer (C:Σ(cn))
2/15 (10:00)	WPN	Gampaha	Sapugaskanda	F9	8,000

Outage Duration1 (d1)	Consumer Number1 (c1)	Outage Duration2 (d2)	Consumer Number2 (c2)	Outage Duration3 (d3)	Consumer Number3 (c3)
30 (10:30)	500	120 (12:00)	1500	-	-

Total Outage duration (D:Σ(dn×cn))	Failure Aspect	Outage types	Cause of outage
195,000	OC	A	A15

 92

Details of failure record (draft)



Sapugaskanda/F09(DD2)

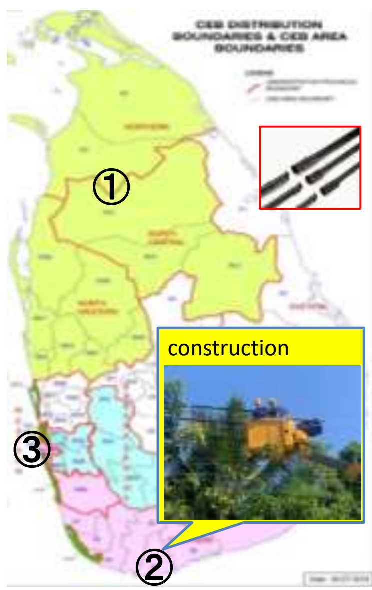
ARC Pilot Project Site

Pilot Project Status

Installed in all the target sites

Equipment	Pilot Project Site		
	DD1	DD4	LECO
Abrasion Resistant Cover for Conductor	①PoojaNagaraya	②Matara F1	③ Kaluwamodara F-Moragalla

ARC		DD1	DD4	LECO
Pilot feeder	Unit	Pooja Nagaraya	Matara F1	Kaluwamodara Moragalla Feeder
SAIFI '19	[min]	10	2.4	56.2
SAIFI '23	[min]	**3.8**	**1.3**	**37.5**
Effect	[min]	-6.2	-1.1	-18.7
Effect	%	-62	-45.9	-33.3
SAIDI '19	[min]	1,192	110	1,450
SAIDI '23	[min]	**397**	**53**	**967**
Effect	[min]	-795	-57	-483
Effect	%	-66.7	-51.8	-33.4



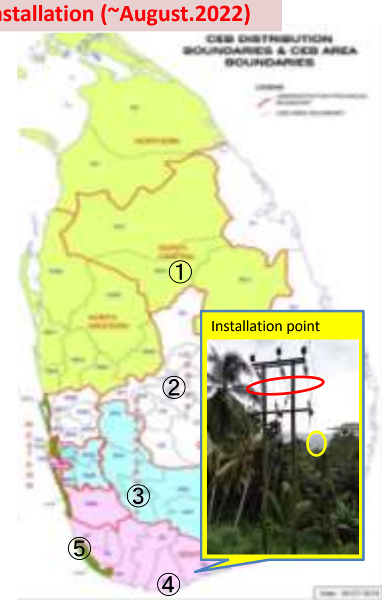
OCI Pilot Project Site

Pilot Project Status

Delivered (June.2022)
Installation (~August.2022)

Equipment	Pilot Project Site				
	DD1	DD2	DD3	DD4	LECO
Over Current Indicator [OCI]	① Habarana F7	② Kiribath -kumbura F9	③ Ratnapura F2	④ Deniyaya F4	⑤ Beligaha F-Boossa

OCI		DD1	DD2	DD3	DD4	LECO
Pilot feeder		Habarana F7	Kiribathkumbura	Ratnapura F2	Deniyaya F4	Beligaha BoosaFeeder
	Unit					
SAIDI '19	[min]	4,620	1,021	637.6	6,052	3,734
SAIDI '23	[min]	4,126	955	355.9	5,054	3,437
Effect	[min]	-494	-66	-282	-998	-297
Effect	%	-10.7	-6.5	-44.2	-16.5	-7.9



Results(value)

		DD1			DD2			DD3			DD4			LECO		
		Before	After	Effect [%] [min]	Before	After	Effect [%] [min]	Before	After	Effect [%] [min]	Before	After	Effect [%] [min]	Before	After	Effect [%] [min]
OCI1	SAIDI [min]	4620	4126	-10.7 **-494**	552.1	513.5	-7.0 -38.6	37	16.4	-55.7 -21	6052	5054	-16.5 **-998**	1882	1826	-3.0 -56
OCI2		2862	2840	-0.8 -22	1021	955	-6.5 **-66**	637.6	355.9	-44.2 **-282**	2574	2310	-10.3 -264	3101	3049	-1.7 -52
OCI3		1049	920	-12.3 -129	434	372	-14.3 -62	34	26	-23.6 -8	8494	7498	-11.8 -996	3734	3437	-7.9 **-297**
Cover	SAIDI	1192	397	-66.7 -795							110	53	-51.8 -57	1450	967	-33.4 -483
	SAIFI	10	3.8	-62 -6.2							2.4	1.3	-45.9 -1.1	56.2	37.5	-33.3 -18.7
GFD	SAIDI [min]	490	277	-43.5 -213	F6 552.1	F6 386.5	-30.0 -166	F3 68.37	F3 36.47	-46.7 -31.9	F2 417	F2 216	-48.3 -201	Wewalamilla 4565	Wewalamilla 3241	-29.1 -1324

Automatic Detection of Detailed Outage Area by Smart Meter

01 Status of Smart Meter Introduction in CEB/LECO

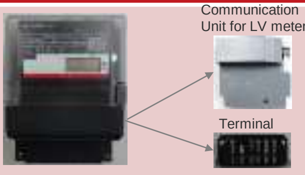
the Annual Report 2020

According to the Annual Report 2020 shown at the bottom,
the data obtained by smart meters can be linked to the CEB Assist and utilized for remote meter reading and bill generation.
Meanwhile, CEB have been utilizing the CEB Assist to grasp and share outage information
by receiving customer inquiries and sharing the outage information for outage recovery.

It seems other smart meter data such as an reaction to a polling are not automatically utilized through the CEB Assist for failure outage area detection (locating). Also, such smart meter data can be utilized to detect a broken wire which might be fallen down to the ground in a very dangerous state. Therefore, we would like to introduce the utilization idea of smart meter data in the next WG activity, though there is no procurement of smart meters, etc. in this project. We think this idea will be helpful for CEB to improve power supply reliability when a lot of smart meters are introduced in future.

02 Outline of MV/LV Smart Meters in CEPCO

- A smart meter is a meter with function that enable us to obtain measurements remotely like 30min interval kWh, voltage and others.
- Smart meter for LV also has function for open/shut and load limit setting.
- CEPCO is addressing to utilize these function and data obtained for not only promoting energy usage efficiency but also improvement our work efficiency, asset investment optimization and restore service more faster.

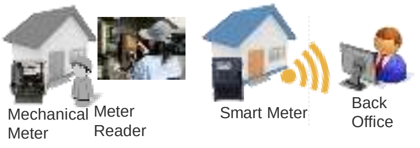
LV Smart Meter	HV Smart Meter
	
• Measuring & Recording Bidirectional kWh （30min interval） • Measuring instantaneous value（V / A / W） • Load Limit Setting※ • Open/Shut function※ • Communication（920MHz or LTE or PLC） • Interface of external device (such as HEMS) ※only for single phase and rated capacity is 60A or below	• Measuring & Recording unidirectional kWh, kVar, kW （30min interval） • TOU Calendar • Communication（920MHz or LTE） • Interface of external device (such as HEMS)

03 Benefit of utilizing Smart Meter (Work Efficiency Improvement) in CEPCO

- More than half of conventional field work (meter reading & start/stop service, etc.) is automatically carried out since starting smart meter installation.
- By utilizing smart meter to improving the work efficiency of conventional fieldwork, we optimize human resources like relocating field engineers from traditional works to more essential jobs like patrol inspection for distribution asset management.

①Automatic Meter reading

Conventional Work ➡ Current Work



Conventional Work	Current Work
Checking usage at site by meter reader	Usage data is collected automatically by AMI
・Misreading & Wrong billing ・Labor accident at field	・Accurate reading & billing ・Avoid labor accident

②Remote Switch Control

Conventional Work ➡ Current Work

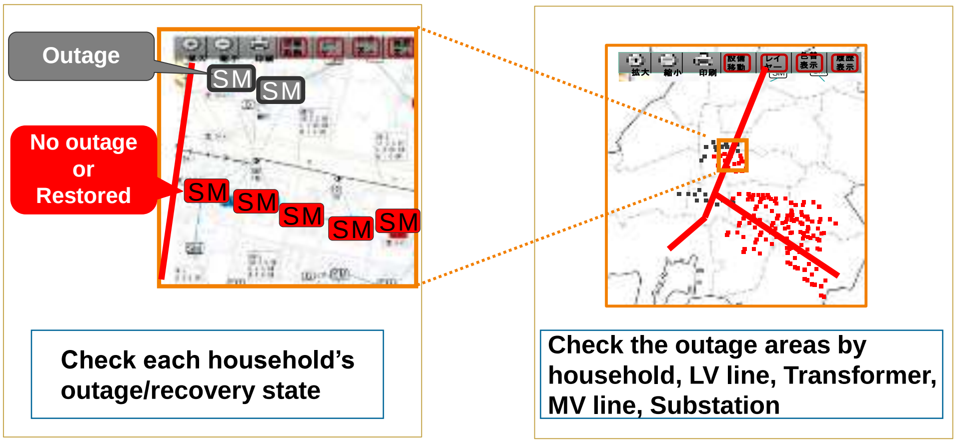
Conventional Work	Current Work
Connect or remove the meter wire by field crew.	Remote turn on/off from back office.
・Mistake of meter works ・Labor accident at field	・Reduce the travel and work time ・Avoid labor accident

More than 60% of conventional field work（monthly/temporary meter reading and start/stop） is automatically and correctly carried out through AMI system.

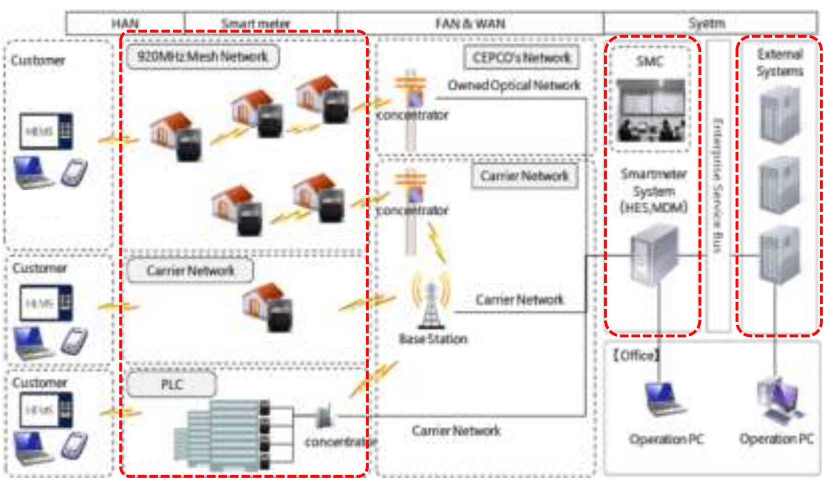
04 | Outage Area Detection by Utilizing Smart Meter

Smart meters can be used as sensors to detect an outage area, figure out the scale of an outage and dispatch an appropriate number of workers to achieve quick restoration.

When an outage occurs or after the outage is recovered, …

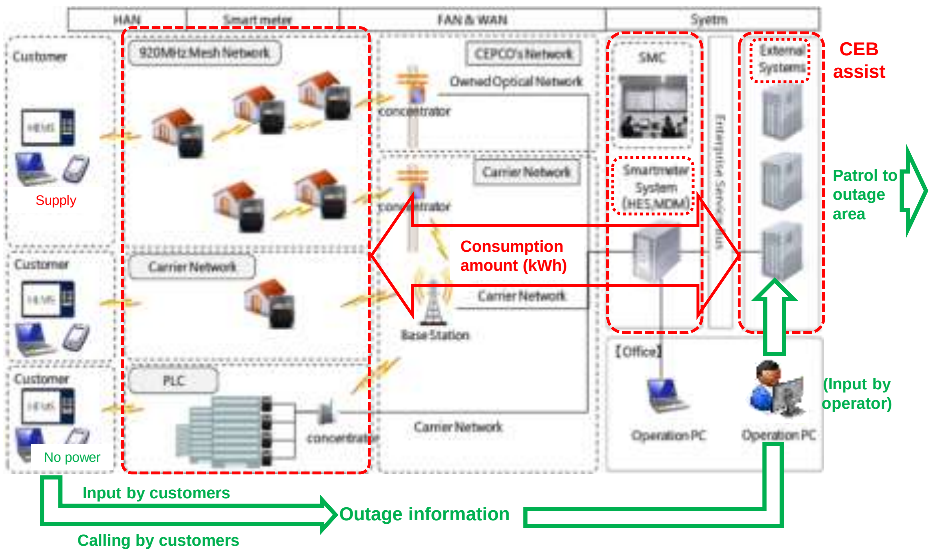


05-1 | System Link Image of SM data to External System

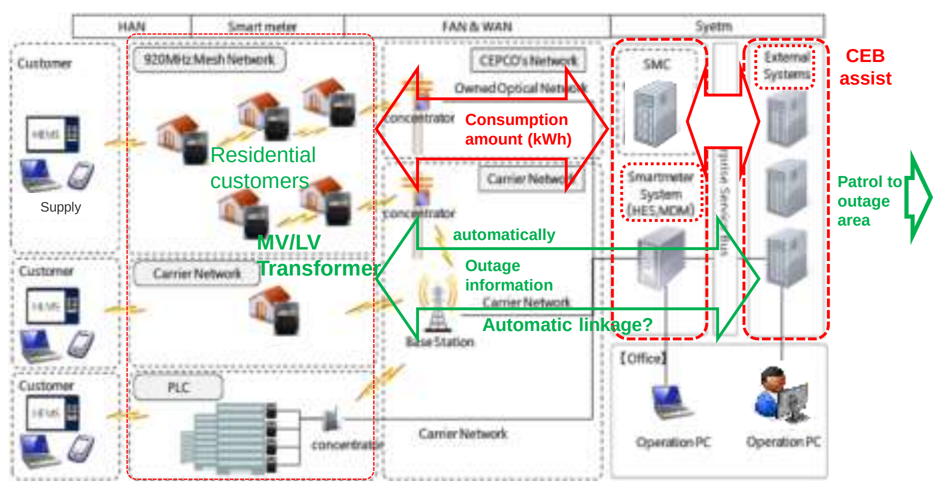


(Smart Meter ⇔ HES ⇔ MDM ⇔ External Systems)

05-2 Consumption/Outage Information Flow to CEB Assist



05-3 Automatic Outage Area Detection by Utilizing Smart Meter



Outage area can be detected automatically, more rapidly, more exactly, more efficiently without operator/customer work.

Outage of Transformer?

Polling to one of the SMs in an MV/LV transformer(T/F)

Response → **No outage of the T/F**

No response → Polling to all the SMs under the T/F

- Response from at least one SM → **No outage of the T/F** (Partial outage in the LV line or communication failure)
- No response from all the SM → **Outage of the T/F**

Other Transformers

(The same way)→Outage of other T/Fs→Possibility of MV line outage

Classification of Grid Interconnection in Japan

Classification of Grid Interconnection in Japan

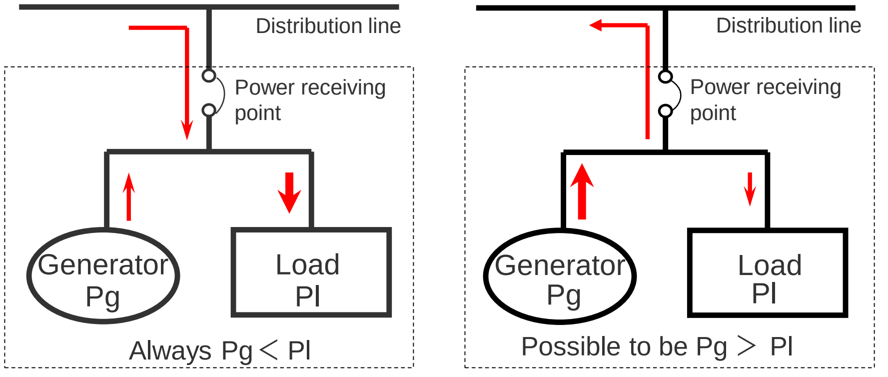
Classification of grid interconnection	Type of generation facility	Output power capacity per customer	With or without reverse power flow*2
LV distribution line	Generation facility through PCS	No more than 50 kW in standard	With / Without
	AC generation facility (without PCS)		Without
MV distribution line	Generation facility through PCS or AC generation facility (without PCS)	No more than 2,000 kW in standard	With / Without
Spot network distribution line	Generation facility through PCS or AC generation facility (without PCS)	No more than 10,000 kW in standard	Without
HV distribution line *1		No more than 2,000 kW in standard	With / Without

*1 When connecting to an electric line treated as a distribution line of 35 kV or less (20 kV class distribution line), it is possible to comply with the technical requirements for interconnection to a high-voltage distribution line (however, the power capacity per installer is in principle. It is less than 10,000 kW.

*2 The presence or absence of reverse power flow is determined by the actual power flow direction (not whether there is a power sale contract).

Glossary (Reverse Power Flow)

①Without reverse power flow ②With reverse power flow



＊Relations between generator and customer load capacities

・There is a reverse flow if the load capacity is smaller than the output of the power generation equipment

・No reverse flow if the load capacity is larger than the output of the power generation equipment

Judge by the direction of active power at a power receiving point (Current flow direction)

Classification of Grid Interconnection in Japan

The classification of interconnection is applied according to the voltage class and form of the interconnection system, regardless of the output voltage of the power generation facility.

Ex) When a customer who receives power from a MV distribution line installs a LV power generation facility, etc. on the premises and connects the grid via a step-up transformer,
⇒ Applying technical requirements for MV distribution lines

However, when the output capacity of the power generation equipment, etc. is extremely smaller than the contracted power, the grid can be connected in accordance with the lower division of the voltage in the contracted electricity. [LV deemed interconnection]

(Comment) "The output capacity is extremely small compared to the contracted power" means

- power generation capacity is less than 50 kW
- as a rough indication, the output capacity of power generation equipment, etc. is approximately 5% or less of the contracted power.
  However, if the output capacity of the power generation equipment is always small with respect to the minimum load on the premises and it is possible to quickly prevent islanding, it is possible to operate beyond this rough indication value.

Ex) When installing a 10 kW (5% of contract) power generation facility in a MV customer premises with a contract power of 200 kW
⇒Applying technical requirements for LV distribution lines

Guideline
regarding Power Quality Securement for Grid Interconnection Requirement in Japan

Purpose of Guideline and Basic Concept in Japan

Purpose

To clarify "technical requirements necessary to enable power generation equipment to be connected to commercial power system," and to introduce it in an orderly manner and "secure human and equipment safety and maintain supply reliability"

Basic Concept

By solving technical problems (taking measures), for the first time, interconnection with the power system becomes possible.

(1) Do not adversely affect other customers in terms of supply reliability (power outage, etc.) and power quality (voltage, frequency, etc.).

(2) Ensure the safety of the public and workers, and do not adversely affect the power supply facility or the facilities of other customers.

Orientation of Guideline in Japan

There is no legal regulation (compulsory force) like the electrical equipment technical standard in the “Guideline for grid interconnection technology requirements for ensuring power quality”. This is **a standard index** for discussions to establish a grid interconnection with an electric utility that operates power grids.

Grid Interconnection Code in Japan

Purpose of Grid Interconnection Code

Purpose

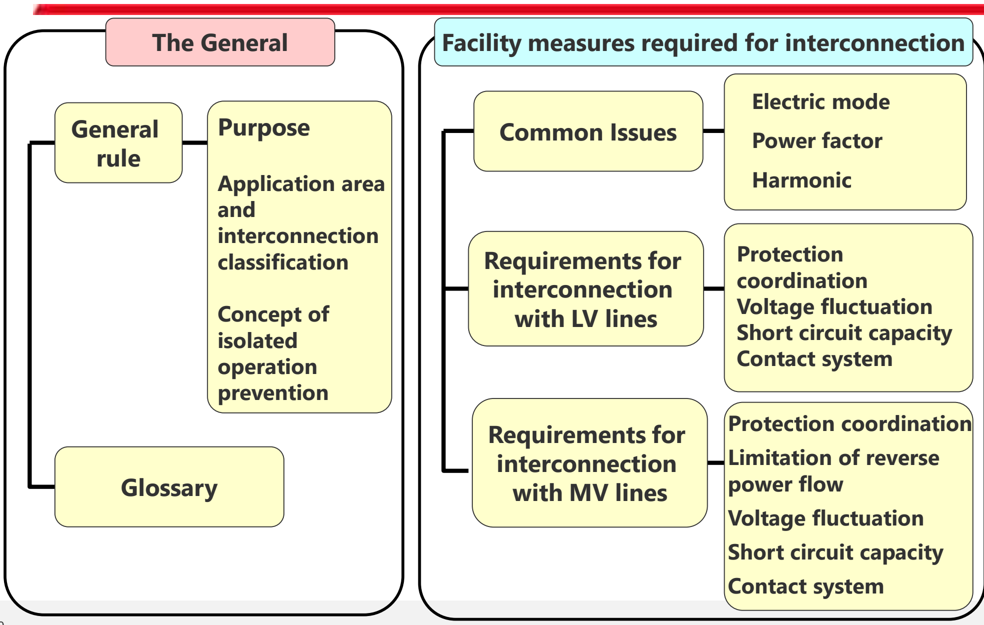
Explanation and Complement of Electrical equipment technical standards and Guideline

- Based on the purpose of the guideline, it has been established as a private voluntary regulation that is useful for practitioners involved in the grid interconnection of distributed power sources.
- The grid interconnection regulations are private regulations that are not legally enforceable. (Similar to extension regulations and high voltage power receiving equipment regulations)
- However, in compliance with the technical standards based on the Electricity Business Law, the standards are fairly and neutrally set by each company, manufacturer, academic expert, and related organizations, which is a common rule for interconnection.

Conducted various technical studies and discussions with customers based on the grid interconnection regulations

9

Formation of Grid Interconnection Code

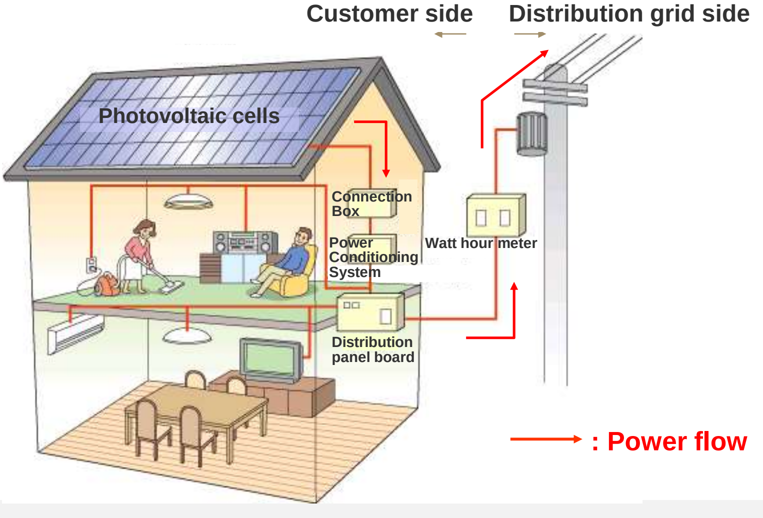


10

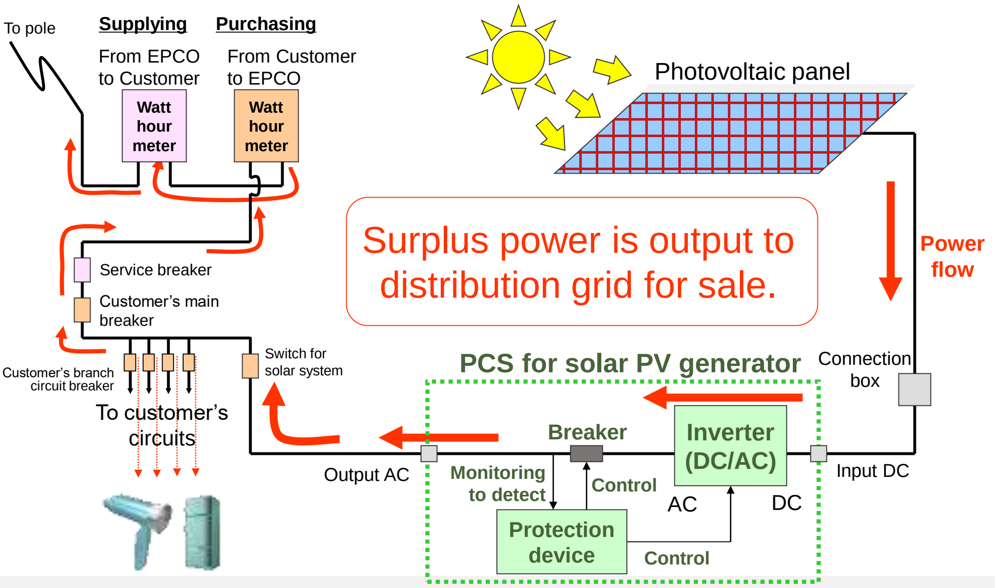
Outline of Solar PV Generation System

Brief Overview of Solar PV Generation System

Generated power flows to a distribution grid side and is consumed in a customer house.



Brief Overview of Solar PV Generation System



Brief Overview of Solar PV Generation System

PCS (Power Conditioning System) consists of

- Inverter
  Convert DC to AC
- Protection device for grid interconnection
  Prevention of islanding
  Control of frequency, voltage and current, etc.
  High quality output without voltage fluctuation, harmonics, etc.
- Breaker for grid interconnection
  Stop and disconnect in case of emergency

Rooftop PV Connection to 400 V Line

Contract Types of RE Purchase

	Net Metering	Net Accounting	Net Plus
Generation power	Balancing out by consumption amount. Pay for the consumption subtracted by generation. Keep as credit for next month (for several months), if generation amount exceeds consumption amount. Never pay to the owner.	Purchase the rest of consumption. Pay by standard tariff rate, if consumption amount exceeds generation amount. Upper limitation of generation capacity (determined by contract).	Purchase all generation power. Upper limitation of generation capacity (determined by contract).
Unit price for purchase	N/A (Balancing each other out)	22.00Rs.(0th~7th year), 15.50Rs.(8th~20th year)	22.00Rs.(0th~7th year), 15.50Rs. (8th~20th year)
Contract term	For 20 years	For 20 years	For 20 years
Applicable RE	All RE	Only rooftop PV	Only rooftop PV
Capacity limit	Based on each contract	Based on each contract	Based on each contract

Rooftop PV Projects Introduced by Donors

Pilot projects (about 22 projects) were introduced in 2014 to promote rooftop PV with capital subsidy and concessionary financing funded by ADB.

Presently another project for rooftop PV up to 50kW capacity is in operation with concessionary financing (interest rate: 6%) funded by ADB.

If any projects for rooftop PV, please inform.

Solar PV Introduction in Sri Lanka

Program of introducing rooftop PV, which started from 2016 for acceleration, 200MW rooftop PV would be introduced by 2020 in which LTGER 2018-37 describes, has already achieved the target.

Up to Dec 2018 by SBS progress sheet
- CEB ~130 MW
- LECO ~40 MW

At present
- CEB (as of JAN 2020)
  - 57.36 MW (ground mounted)
  - 194.54 MW (rooftop)
  - 252 MW (total)
- LECO (as of DEC 2019)
  - 64 MW (total)

Difference between rooftop PV and ground mounted PV?

Utilization of Storage Battery System

in Distribution Grid

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

- ■ Suppression of capital investment
  - ✓Power flow control
  - ✓Off-grid performance
- ■ Improvement of power quality
  - ✓Constant power factor control
  - ✓Reactive power direct command control
  - ✓Target voltage constant control
  - ✓Voltage fluctuation suppression control
  - ✓Semi-off grid performance
- ■ Secure of adjustability
  - ✓Output fluctuations suppression
  - ✓Adjusting power procurement cost suppression
- ■ Expansion of income
  - ✓Originally suppressed non-firm cheap power utilization

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■ Suppression of capital investment

✓By controlling the charging and discharging of the storage battery, it is possible to avoid overload (reinforcement work) of the distribution line. [Power flow control] (cf.) Demand response

Item	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A) class?]

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■ Suppression of capital investment

✓By combining a naturally fluctuating power source such as PV and a storage battery in mountainous areas and performing charge / discharge control, off-grid is performed, equipment renewal costs and maintenance costs might be suppressed, and resilience might be strengthened.

Item	Target
Distribution feeder	Distribution line with long length of no-load part and a little load at the end
Installation site	Near the end of the distribution line (Load side of the no-load part)
SBS capacity	Capacity that can supply load for several days Contract: ***kW (** A) and *** kWh?

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■ Improvement of power quality

✓When the storage battery controls charging, it can also outputs reactive power at the specified power factor to suppress the voltage drop [constant power factor control].

Item	Target
Distribution feeder	Distribution line where storage batteries are interconnected
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A） class?]

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■ Improvement of power quality

✓By outputting reactive power from the storage battery, the voltage in the distribution line that has risen due to power generation such as solar PV is lowered as a whole.
[Reactive power direct command control]

Item	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A） class?]

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■Improvement of power quality

✓In order to suppress quick voltage fluctuations due to fluctuations in solar PV generation, reactive power is controlled to keep the voltage of the storage battery a constant level, voltage deviations and the frequent SVR tap operations are reduced. [Target voltage constant control].

Item	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A） class?]

Utilization of Storage Battery System
-Beneficial for Distribution System Operator-

■Improvement of power quality

✓By setting the average voltage in the past 10 minutes at the interconnection point as a target and controlling the reactive power so that the voltage at the interconnection point is kept within the dead zone of the target voltage, the voltage deviation and the frequent SVR tap operations are reduced. [Voltage fluctuation suppression control]

Item	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A） class?]

Utilization of Storage Battery System

-Beneficial for Distribution System Operator-

■Improvement of power quality

✓In a distribution line with a long length, a semi-off grid (shortening the length) is performed to suppress flicker, etc. by combining a naturally fluctuating power source such as a solar PV generator and a storage battery and controlling charge / discharge.

Itemc	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A) class?]

Utilization of Storage Battery System

-Beneficial for Distribution System Operator-

■Secure of adjustability

✓It is possible to suppress output fluctuations by PV and wind power generation, by installing storage batteries in PV and wind power plants and controlling charge and discharge.

Item	Target
Distribution feeder	Distribution line where storage batteries are interconnected
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A) class?]

Utilization of Storage Battery System

-Beneficial for Distribution System Operator-

■Secure of adjustability

✓Is it possible to adjust supply and demand (suppress procurement costs) by installing a storage battery in the system and controlling charge / discharge as a power source for adjusting power (power source for publicly offered adjustment power).

Itemc	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A) class?]

Utilization of Storage Battery System

-Beneficial for Distribution System Operator-

■Expansion of income

✓A business in which the generated power that is originally suppressed is purchased cheaply from a power generation company connected as non-firm contract, and the storage battery connected to the grid is charged (discharged at night).

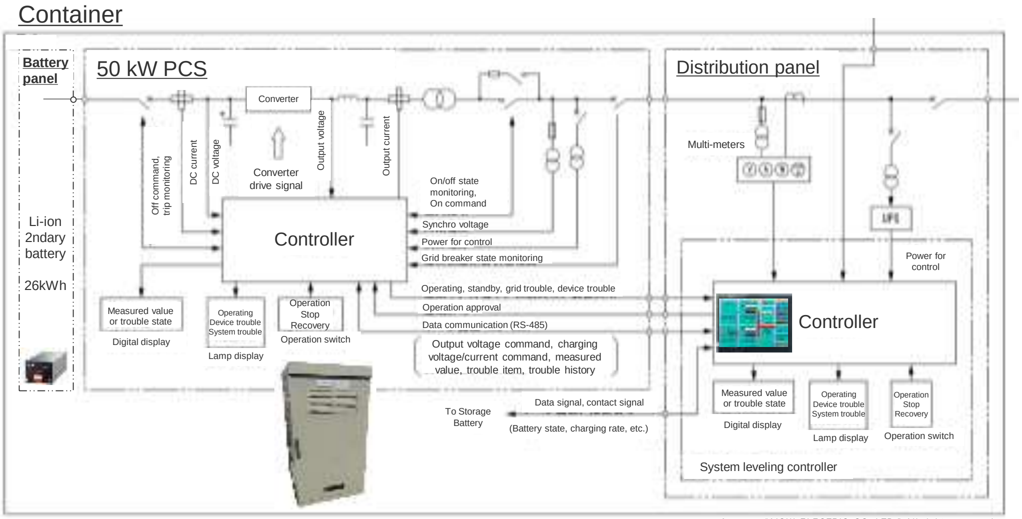
Itemc	Target
Distribution feeder	Distribution line that requires reinforcement of distribution line such as thickening wire due to overload
Installation site	In the middle of distribution line (Load side from the part where thickening is required)
SBS capacity	The capacity which can afford to keep the line current less than rated capacity [***kWh (**A) class?]

Sample of BESS Main Specifications

Ex1) Specifications of BESS (50 kW- 0.5 hour)

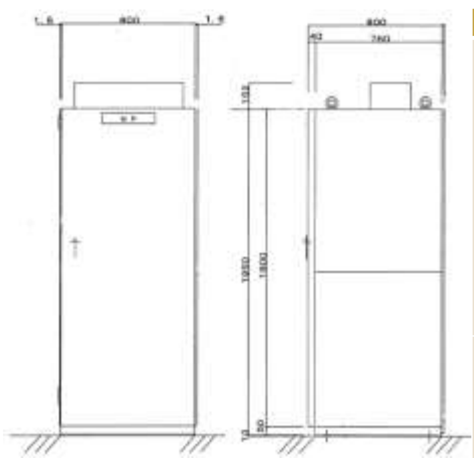
Items		Specifications	Remarks
Configuration	Container	Body: Aluminum, Basement: Steal structure Battery panel, PCS panel, distribution panel, etc. contained	Air conditioner required
	Battery panel	Li-ion secondary battery: 26kWh	Installation in a container
	PCS	50kW 3φ400V	Installation in a container Complying with interconnection code (JEAG9701)
	Distribution panel	3φ400V Leveling controller included Multi-meters for measuring BESS output	Installation in a container
	Multi-meters	SPP output measuring	Installation in a target point such as mass solar PV generators
Function	Power leveling	Leveling rapid output fluctuation of solar PV generation	Ex) suppression from 43kW/s to 0.05kW/s
	Manual charge / discharge	Protection of charging / discharging excess of storage battery	Constant voltage / constant current

Ex1) Configuration of BESS



Reference: "AICHI ELECTRIC CO.,LTD." All rights reserved.

Ex1) Specification of Storage Battery

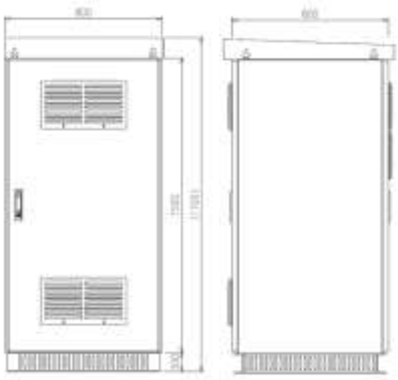


Drawing of LiB Storage Battery

	Items	Specifications	Remarks
Storage battery panel	Type	Lithium-ion secondary cell	
	Capacity (kW)	26 kWh	2 kWh x 13 modules
	String configuration	1 module x 13 series	
	Nominal voltage	DC 665.6V	= 51.2 V x 13 series
	Voltage range	DC 559~728 V	
	Size	800 W x 800 D x 1,900 H	
	Weight	Approx. 800 kg	
	Management		Battery management system attached
Battery module	Cell number	224 cells	16 series x 14 parallels
	Rated capacity (kWh)	2 kWh	= 51.2 V x 39.5 Ah
	Rated capacity (Ah)	39.5 Ah	= 2.85 Ah x 14 parallels
	Nominal voltage	DC 51.2 V	= 3.2 V x 16 series
	Charging voltage	56.0 V	

Reference: AICHI ELECTRIC CO.,LTD.

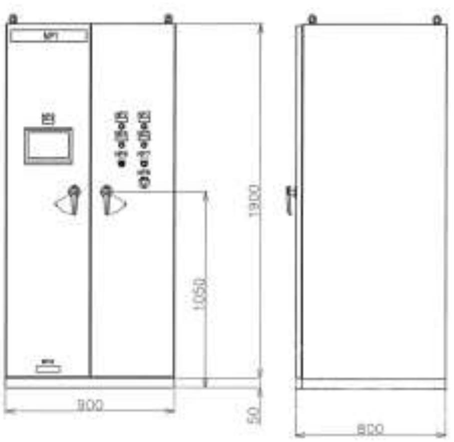
Ex1) Specifications of Power Conditioning System



Drawing of PCS Panel

Items	Specifications
Type of rating	Continuous
Rated input voltage	DC 500 V
Acceptable input voltage	DC 750 V
Input voltage operating range	DC 420~750 V
Rated output voltage	AC 400 V
Rated frequency	50/60 Hz
Electrical system	Three-phase three-wire system
Output voltage operating range	AC 400 V ± 10%
Rated output	50 kW
Power conversion efficiency	94% or more (at maximum)
Output power factor	0.95 or more
Output current distortion factor	5% or less (at rated output)
Output current harmonics content rate	3% or less in each phase (at rated output)
Size	800 W x 800 D x 1,700 H
Weight	570 kg

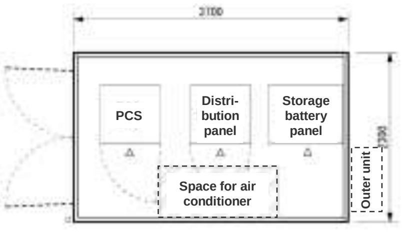
Ex1) Specifications of Distribution Panel



Drawing of Distribution Panel

Items	Specifications
Type of rating	Continuous
Rated capacity	60 kVA
Rated voltage	AC 400 V
Rated frequency	50/60 Hz
Electrical system	Three-phase three-wire system
Operation switch	Operation/Stop, emergency stop, failure recovery, etc.
Indicator lamp	Operation/stop, failure, etc.
Operation/display panel	Touch panel liquid crystal display, Displaying solar PV output, storage battery output, etc.
Size	900 W x 800 D x 1,700 H
Weight	350 kg
Remarks	Leveling controller and communication software included in advance

Ex1) Specification of Container

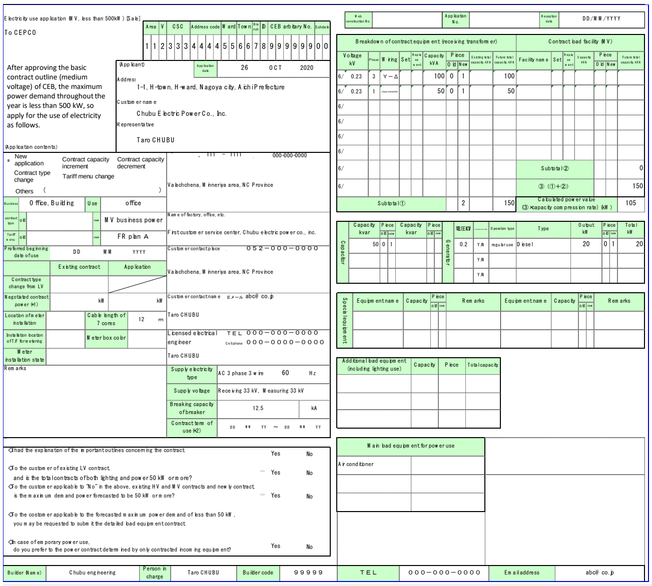


Drawing of Container

Items	Specifications
Environment conditions	Salt resistant, Snow resistant of 1 m
Outer panel	Aluminum
Exterior paint	Fluororesin coating
Thermal insulation	Polystyrene foam
Base frame	Steel structure (Hot-dip galvanized finish)
Basement (Floor)	Steel, Underfloor thermal insulation
Cable inlet	Lower assumed
Size	3,700 W x 2,300 D x 2,900 H
Weight	3,000 kg
Others	Distribution panel for home, Indoor light, Power outlet
Remarks	Air conditioner required Easy to assemble

Application for Grid Interconnection of BESS with Documents and Drawings

Application Form for Grid Interconnection of Storage Battery System



Electricity use application (MV, less than 500kW) [Sale]

To CEPCO

Area	V	CSC			Address code				Ward		Town		Branch	ID	CEB arbitrary No.						Schedule	
1	1	2	3	3	3	4	4	4	4	5	5	6	6	7	8	9	9	9	9	9	0	0

After approving the basic contract outline (medium voltage) of CEB, the maximum power demand throughout the year is less than 500 kW, so apply for the use of electricity as follows.

(Applicant) Application date: 26 OCT 2020

Address: 1-1, H-town, H-ward, Nagoya city, Aichi Prefecture

Customer name: Chubu Electric Power Co., Inc.

Representative: Taro CHUBU

(Application contents)

New application / Contract capacity increment / Contract capacity decrement / Contract type change / Tariff menu change / Others ( )

000-000-0000

Valachchena, Minneriya area, NC Province

Business	Office, Building	Use	office
contract type	old	new	MV business power
Tariff menu	old	new	FR plan A
Preferred beginning date of use	DD MM YYYY		
	Existing contract	Application	
Contract type change from LV			
Negotiated contract power (*1)	kW	kW	
Location of meter installation		Cable length of 7 cores	12 m
Installation location of T,F for metering		Meter box color	
Meter installation state			
Remarks			

Name of factory, office, etc.: First customer service center, Chubu electric power co., inc.

Customer contact place: 052-000-0000

Valachchena, Minneriya area, NC Province

Customer contact name: Eメール abc@ co.jp

Taro CHUBU

Licensed electrical engineer: TEL 000-000-0000, Cellphone 000-0000-0000

Taro CHUBU

Supply electricity type	AC 3 phase 3 wire 60 Hz
Supply voltage	Receiving 33 kV, Measuring 33 kV
Breaking capacity of breaker	12.5 kA
Contract term of use (*2)	DD MM YY ~ DD MM YY

	Yes	No
◇I had the explanation of the important outlines concerning the contract.	Yes	No
◇To the customer of existing LV contract, and is the total contracts of both lighting and power 50 kW or more?	Yes	No
◇To the customer applicable to "No" in the above, existing HV and MV contracts and newly contract, is the maximum demand power forecasted to be 50 kW or more?	Yes	No
◇To the costomer applicable to the forecasted maximum power demand of less than 50 kW, you may be requested to submit the detailed load equipment contract.		
◇In case of temporary power use, do you prefer to the power contract determined by only contracted incoming equipment?	Yes	No

Web construction No.		Application No.		Reception data	DD/MM/YYYY

Breakdown of contract equipment (receiving transformer) / Contract load facility (MV)

Voltage kV	Phase	Wiring	Set	Replacement	Capacity kVA	Piece Old	Piece New	Existing total capacity, kVA	Future total capacity, kVA	Facility name	Set	Replacement	Capacity kVA	Piece Old	Piece New	Future total capacity, kVA
6/ 0.23	3	Y−Δ			100	0	1		100							
6/ 0.23	1	single connection			50	0	1		50							
6/																
6/																
6/																
6/																
6/										Subtotal②						0
6/										③ (①+②)						150
Subtotal①							2		150	Calculated power value (③×capacity compression rate) (kW)						105

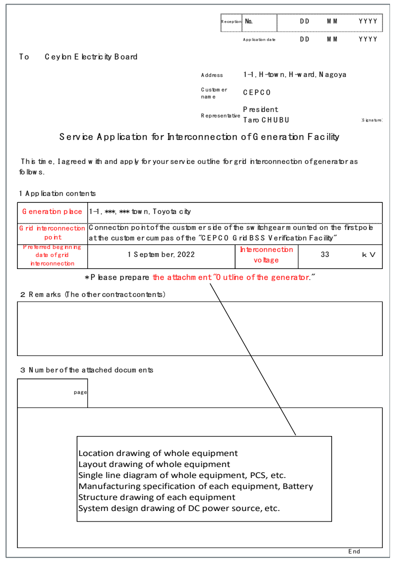
Capacitor: Capacity kvar	Piece old	Piece new	Capacity kvar	Piece old	Piece new	Generator: 電圧kV		Operation type	Type	Output kW	Piece old	Piece new	Total kW
50	0	1				0.2	Y/N	regular use	Diesel	20	0	1	20
							Y/N						
							Y/N						

Special equipment: Equipment name	Capacity	Piece old	Piece new	Remarks	Equipment name	Capacity	Piece old	Piece new	Remarks

Additional load equipment (including lighting use)	Capacity	Piece	Total capacity

Main load equipment for power use	
Air conditioner	

Builder (Name)	Chubu engineering	Person in charge	Taro CHUBU	Builder code	99999	TEL	000-000-0000	Email address	abc@ co.jp



Reception	No.	DD MM YYYY

Application date DD MM YYYY

To Ceylon Electricity Board

Address: 1-1, H-town, H-ward, Nagoya

Customer name: CEPCO

Representative: President Taro CHUBU (Signature)

Service Application for Interconnection of Generation Facility

This time, I agreed with and apply for your service outline for grid interconnection of generator as follows.

1 Application contents

Generation place	1-1, ***, *** town, Toyota city		
Grid interconnection point	Connection point of the customer side of the switchgear mounted on the first pole at the customer cumpas of the "CEPCO Grid BSS Verification Facility"		
Preferred beginning date of grid interconnection	1 September, 2022	Interconnection voltage	33 kV

*Please prepare the attachment "Outline of the generator."

2 Remarks (The other contract contents)

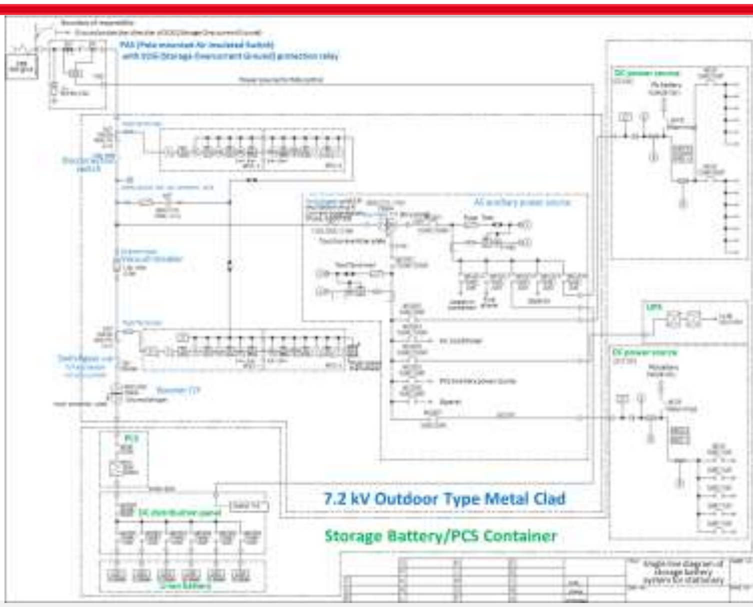
3 Number of the attached documents

page

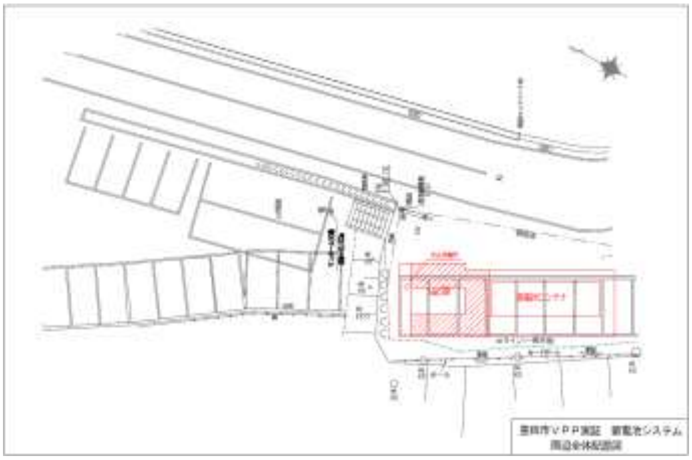
Location drawing of whole equipment
Layout drawing of whole equipment
Single line diagram of whole equipment, PCS, etc.
Manufacturing specification of each equipment, Battery
Structure drawing of each equipment
System design drawing of DC power source, etc.

End

Storage Battery System and Interconnection Facilities

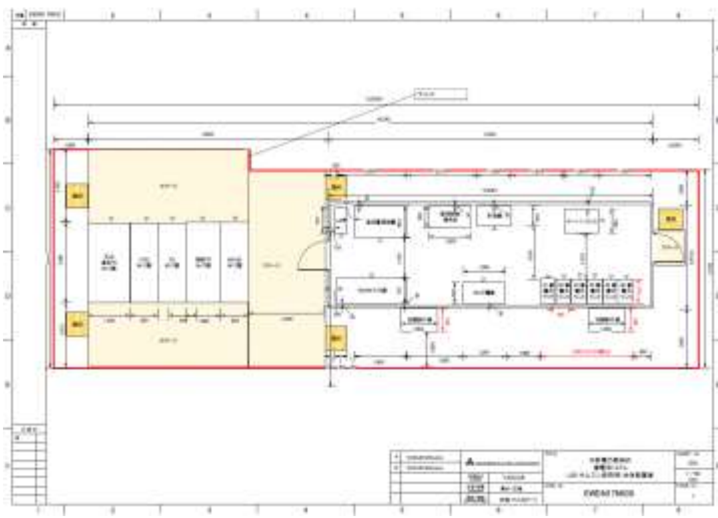


Attachment of Application Form for Grid Interconnection Facilities



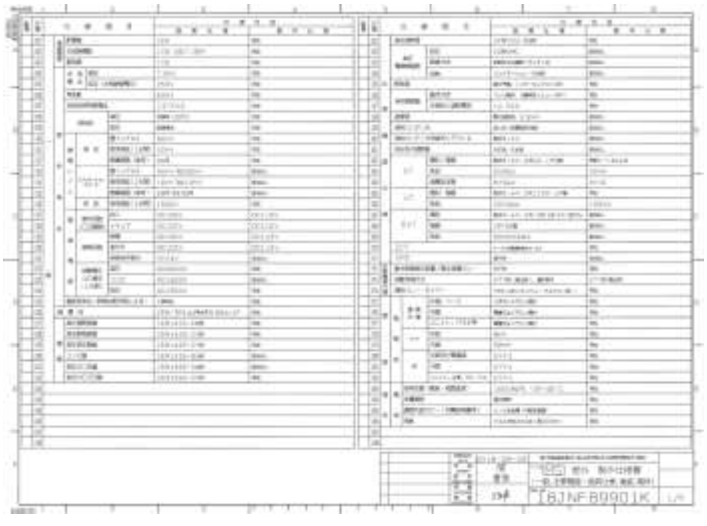
Location of whole equipment

Attachment of Application Form for Grid Interconnection Facilities



Layout of whole equipment

Attachment of Application Form for Grid Interconnection Facilities



Main specification list for manufacturing (1)

Attachment of Application Form for Grid Interconnection Facilities

Main specification list for manufacturing (2)

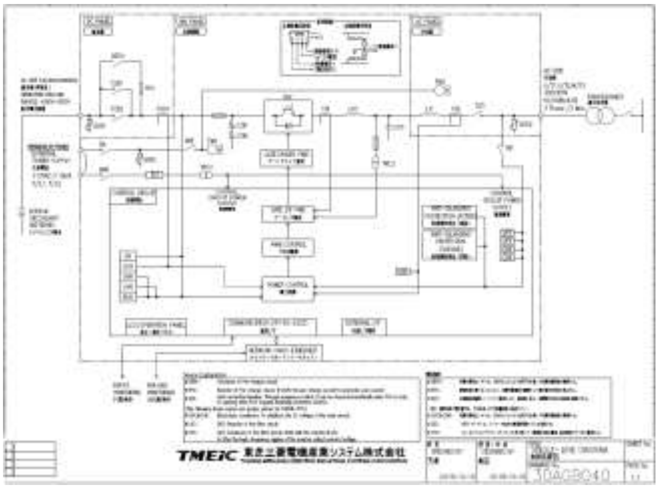
Attachment of Application Form for Grid Interconnection Facilities

Table of schematic diagrams

Attachment of Application Form for Grid Interconnection Facilities

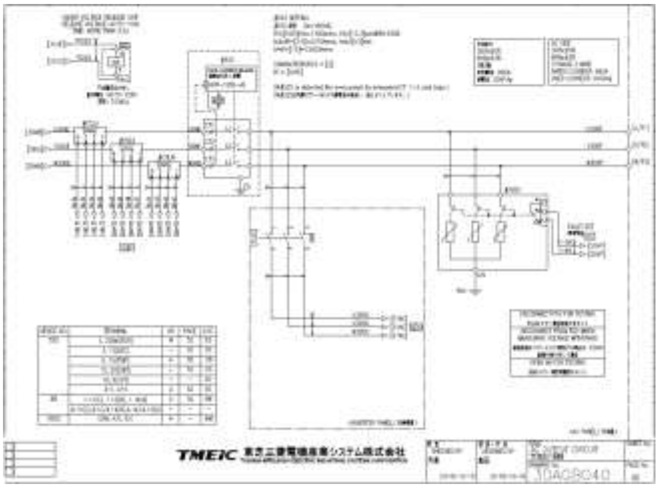
List of ratings

Attachment of Application Form for Grid Interconnection Facilities



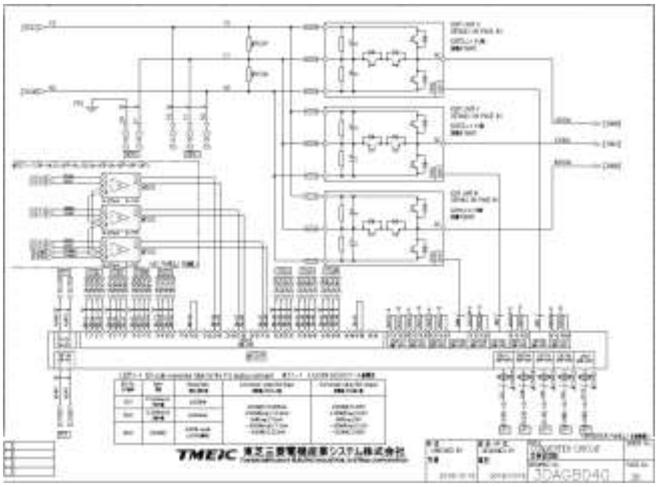
Schematic single line diagram of whole equipment

Attachment of Application Form for Grid Interconnection Facilities



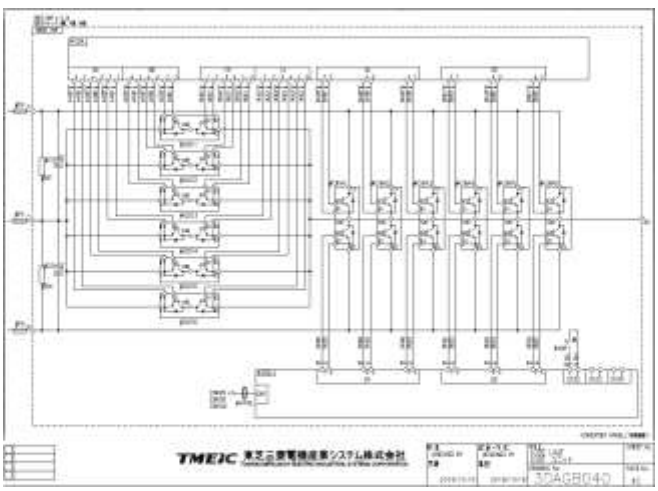
Schematic single line diagram of AC output circuit

Attachment of Application Form for Grid Interconnection Facilities



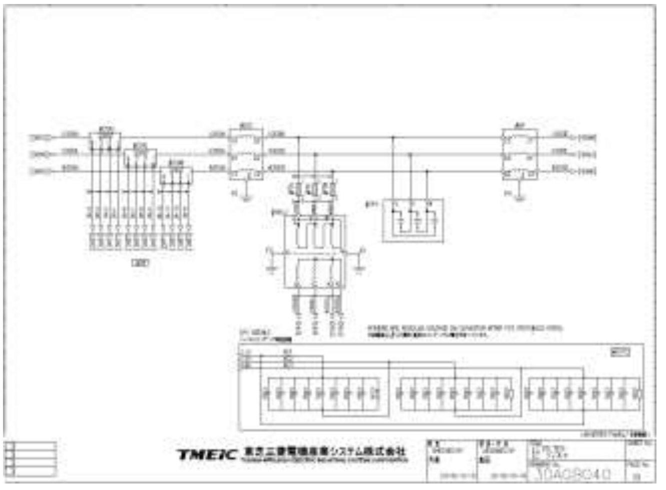
Schematic single line diagram of PCS circuit

Attachment of Application Form for Grid Interconnection Facilities



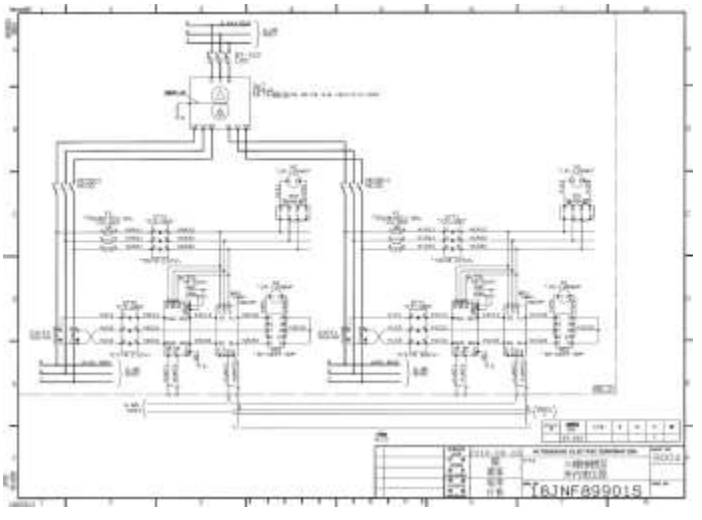
Schematic single line diagram of IGBT unit

Attachment of Application Form for Grid Interconnection Facilities



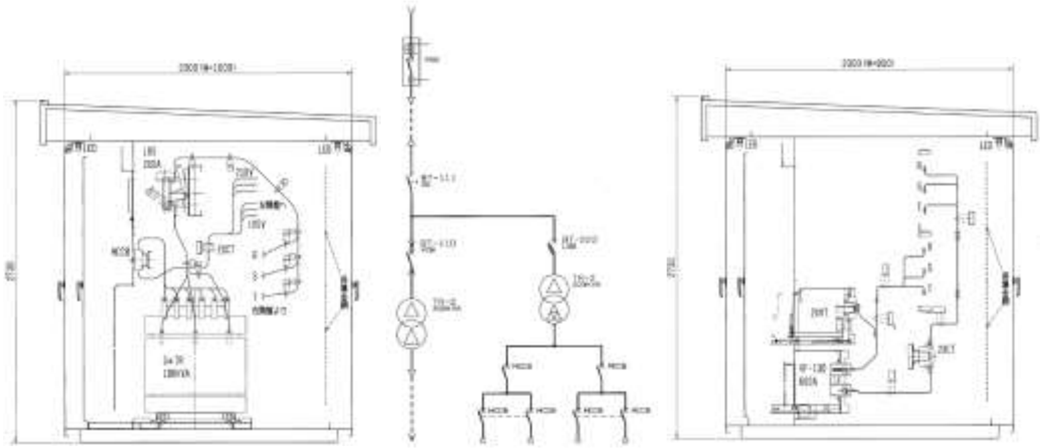
Schematic single line diagram of LC filter

Attachment of Application Form for Grid Interconnection Facilities



Three line diagram for connection of station service transformer

Attachment of Application Form for Grid Interconnection Facilities



Single line diagram of Interlock

Assembly drawings of switchgear and transformer

Attachment of Application Form for Grid Interconnection Facilities

PROTECTION ITEM			SETTING RANGE	STANDARD SETTING VALUE	NOTE	SETTING RECORD			
						FACTORY SETTING			
GRID OVERVOLTAGE (OVR)		DETECTION LEVEL	105 ~ 120% (1% STEP)	115%					
		DETECTION TIME	0.01 ~ 10.00s (10ms STEP)	1.00s					
GRID UNDERVOLTAGE (UVR)		DETECTION LEVEL	65 ~ 90% (1% STEP)	80%					
		DETECTION TIME	0.01 ~ 10.00s (10ms STEP)	1.00s					
GRID OVERFREQUENCY (OFR)		DETECTION LEVEL	+0.1 ~ +5.0Hz (0.1Hz STEP)	50/60+1.0Hz		50/60+2.0Hz			
		DETECTION TIME	0.01 ~ 15.00s (10ms STEP)	1.00s		4.00s			
GRID UNDERFREQUENCY (UFR)		DETECTION LEVEL	−0.1 ~ −5.0Hz (0.1Hz STEP)	50/60−1.5Hz		50/60−2.0Hz			
		DETECTION TIME	0.01 ~ 15.00s (10ms STEP)	1.00s		4.00s			
ISLANDING CONDITION DETECTION	PASSIVE ANTI-ISLANDING PROTECTION (PDR) (VOLTAGE PHASE JUMP)	DETECTION LEVEL	±1 ~ ±15DEG (1DEG STEP)	[illegible]					
		DETECTION TIME	LESS THAN 300ms (FIX)	LESS THAN 300ms					
		RESTART TIME	5 ~ 600s (1s STEP)	5s					
	ACTIVE ANTI-ISLANDING PROTECTION (SLIP MODE FREQUENCY SHIFT)	DETECTION LEVEL	(FUNDAMENTAL FREQUENCY 12%)(FIX)	±7.2Hz					
		DETECTION ELEMENT	ABNORMAL FREQUENCY (OFR, UFR)	–					
		DISCONNECTION TIME LIMIT	ACCORDING TO THE DETECTION ELEMENT	–					
ANTI-RECLOSING PROTECTION		RESTART TIME	7 ~ 600s (1s STEP)	150s					
FRT SETTING		–	[illegible]	[illegible]					

List of grid protection setting

Attachment of Application Form for Grid Interconnection Facilities

PROTECTION ITEM			SETTING VALUE: DETECTION LEVEL	SETTING VALUE: DETECTION TIME	SETTING VALUE: RESTART TIME	DISPLAY: FAULT LED	DISPLAY: BUZZER RINGING	DISPLAY: FAULT CODE	PROTECTION DEVICE OPERATION: 72B1,2 TRIP	PROTECTION DEVICE OPERATION: INVERTER STOP	PROTECTION DEVICE OPERATION: 52S TRIP	PROTECTION DEVICE OPERATION: RESTART	REMARKS
GRID FAULT	GRID OVERVOLTAGE (OVR)		115%	1.00s	–	BLINKING	–	UF201	–	V	V	V	[illegible]
GRID FAULT	GRID UNDERVOLTAGE (UVR)		80%	1.00s	–	BLINKING	–	UF202	–	V	V	V	[illegible]
GRID FAULT	GRID OVERFREQUENCY (OFR)		+2.0Hz	6.00s	–	BLINKING	–	UF219	–	V	V	V	52.0/62.0Hz
GRID FAULT	GRID UNDERFREQUENCY (UFR)		−2.0Hz	6.00s	–	BLINKING	–	UF220	–	V	V	V	48.0/58.0Hz
GRID FAULT	ISLANDING CONDITION DETECTION	PASSIVE ANTI-ISLANDING(PDR) (VOLTAGE PHASE JUMP)	10DEG	WITHIN 350ms	–	–	–	UF221	–	V	–	V	10DEG
GRID FAULT	ISLANDING CONDITION DETECTION	ACTIVE ANTI-ISLANDING (SLIP MODE FREQUENCY SHIFT)	7.2Hz	–	–	–	–	UF219 or UF220	–	V	V	–	OFR or UFR [illegible]

List of grid protection functions (1)

Interconnection Procedure of BESS

Grid Interconnection Code in Japan

The General

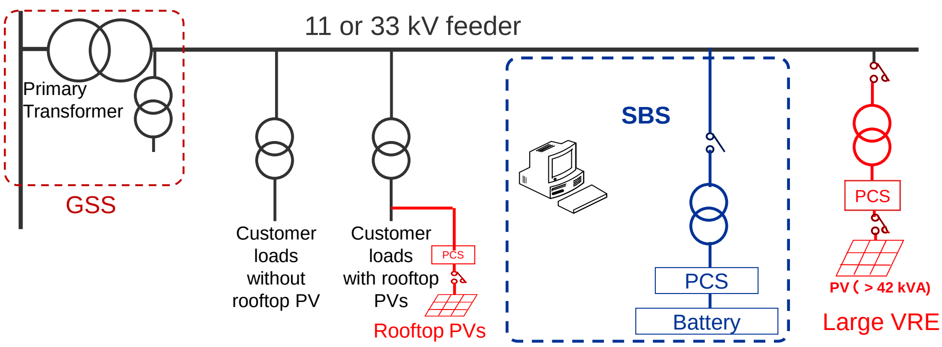
- **General rule**
  - Purpose
  - Application area and interconnection classification
  - Concept of isolated operation prevention
- **Glossary**

Facility measures required for interconnection

- **Common Issues**
  - Electric mode
  - Power factor
  - Harmonic
- **Requirements for interconnection with LV lines**
  - Protection coordination
  - Voltage fluctuation
  - Short circuit capacity
  - Contact system
- **Requirements for interconnection with MV lines**
  - Protection coordination
  - Limitation of reverse power flow
  - Voltage fluctuation
  - Short circuit capacity
  - Contact system

Requirement for Interconnection Condition

Interconnection Condition	Necessary Facility
Protection coordination Voltage fluctuation Short circuit capacity Harmonics Contact system, etc.	Incoming panel Disconnection switch Switchgear Booster transformer Metal clad panel Distribution panel, etc.



Requirement for Safe and Stable Supply Reliability in Sri Lanka

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■ Allowable Voltage range
- 33/36 kV
- 11/12 kV
- 230/400 V

Classification	Normal	Contingency
33/36 kV	-6% ~ +6%	-10% ~ +10%
11/12 kV	-6% ~ +6%	-10% ~ +10%
230/400 V	-6% ~ +6%	-10% ~ +10%

■ Replacement due to overload

Facility	Loading rate criteria
Distribution line	70% for economy 125% for emergency
Distribution substation	80% for normal ?% for emergency
Primary substation	125% for overloading

■ Harmonics
- Total
- Each

When installing the inverse converter (inverter), set the harmonic outflow current to the followings.
・Total current distortion: 5% or less
・Each current distortion: 3% or less

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Procurement and Construction of BESS

Appearance of a Storage Battery System

Inside of Container of Test Facilities

Pilot Project for Load Fluctuation Suppression

How to control a storage battery system by charging/discharging and suppress output power/voltage fluctuation due to short cycle fluctuation of VRE output power

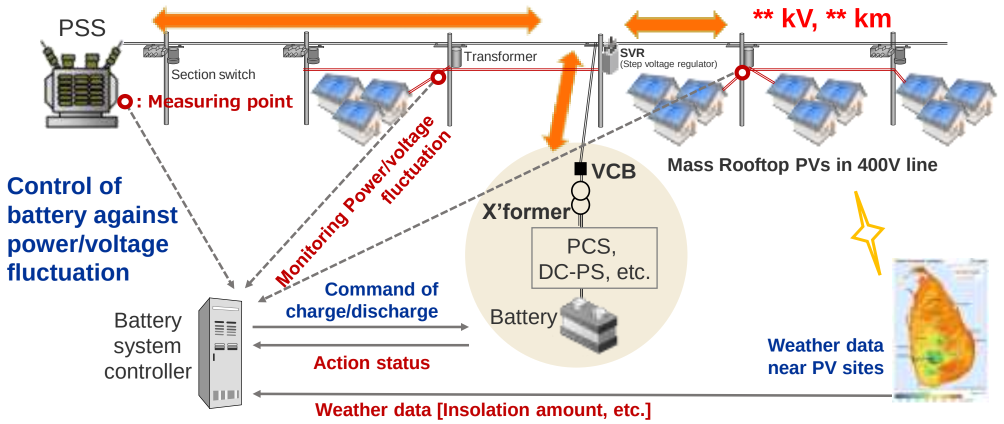
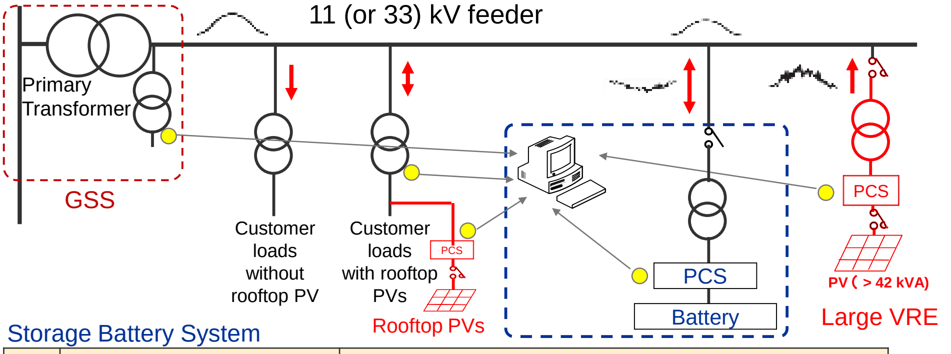


Image of a Pilot Project to suppress load fluctuation

Storage Battery System for Load Fluctuation Suppression



Storage Battery System

No.	Component	Note
1	Storage battery	Li-ion, NaS, Redox flow, Ni-MH, etc.
2	PCS	AC/DC converter, Protection device, Circuit breaker, etc.
3	Battery system controller	To monitor and control power(current)/voltage
4	Ancillary equipment	DC power source, UPS, Distribution panel, etc.
5	Container	To store the whole equipment
6	Incoming panel	Booster transformer, Metal clad panel, distribution panel, etc.

Outline of Load Fluctuation Suppression Test

By monitoring the output power/voltage changes due to mass VRE in a distribution grid and by charging and discharging the power from the storage battery in response to the detected output power/voltage changes, the changes in the power/voltage are suppressed.

Load fluctuation suppression test (Tentative)

Test term	From May to July in 2022
Test place	*** *** PSS, ** kV *** feeder (Max. demand: ***MW) *** city, *** Division, *** Province, Sri Lanka
Test facility	Power conditioning system (** kVA) Li-ion Battery (** kWh), etc.
Test target	**To be selected based on the priority matters in Sri Lanka.** • Keep voltage in an allowable range • Suppress short-cycle output power fluctuation • Improve low voltage in a remote area • Prevent excess of peak reverse power flow • Control voltage to a target value • Shift peak load • Forecast PV generation, etc.

Plan of Pilot Project Preparation (Tentative)

Schedule

(Tentative)	2020			2021				2022				'23
	2nd Q	3rd Q	4th Q	1st Q	2nd Q	3rd Q	4th Q	1st Q	2nd Q	3rd Q	4th Q	1st Q
Selection of a pilot site			★Site visit									
Preparation of facility spec.			★Submission									
Planning and simulation												
Procurement and Construction		Site preparation★							★Adjustment test			
Field test												
Evaluation												

Preparation

No.	EPC, etc.	Contents	Main
1	Engineering	Planning, scheduling, coordination of system interfaces, etc.	JICA expert
2	Procurement	Transportation, Import, Material handling, etc.	JICA expert
3	Installation	Construction for interconnection, wiring, grounding, basement, etc.	CEB
4	Communication	Infrastructure of data communication NW (Existing, OPGW, etc.)	CEB
5	Maintenance		CEB

Technical Report on

BESS Installation in Distribution Network

Technical Reports on BESS Installation in MV/LV Distribution Grid (1)

Author	Title	Chapter and verse
Simone Barcellona, Luigi Piegari, Vincenzo Musolino, Christophe Ballif	Economic viability for residential battery storage systems in grid-connected PV plants	IET Renew. Power Gener., 2018, Vol. 12 Iss. 2, pp. 135-142
Carlos Mateo, Javier Reneses, Andrea Rodriguez-Calvo, Pablo Frías, Álvaro SánchezI	Cost-benefit analysis of battery storage in medium-voltage distribution networks	IET Gener. Transm. Distrib., 2016, Vol. 10, Iss. 3, pp. 815-821
Yongxi Zhang, Shuyun Ren, Zhao Yang Dong, Yan Xu, Ke Meng, Yu Zheng	Optimal placement of battery energy storage in distribution networks considering conservation voltage reduction and stochastic load composition	IET Gener. Transm. Distrib., 2017, Vol. 11 Iss. 15, pp. 3862-3870
Joydeep Mitra	Reliability-Based Sizing of Backup Storage	IEEE Transactions on Power Systems, 2010, Vol. 25, Iss. 2, pp.1198-1199
Luis Gutierrez-Lagos, Kyriacos Petrou, Luis Fernando Ochoa	Quantifying the effects of medium voltage-low voltage distribution network constraints and distributed energy resource reactive power capabilities on aggregators	IET Gener. Transm. Distrib., 2021, Vol.15, pp. 2019-2032.
Lei Huang, Zexin Chen, Qiong Cui, Jiyuan Zhang, Hao Wang, Jie Shu	Optimal planning of renewable energy source and energy storage in a medium- and low voltage distributed AC/DC system in China	J. Eng., 2019, Vol. 2019 Iss. 16, pp. 2354-2361

Technical Reports on BESS Installation in MV/LV Distribution Grid (2)

Author	Title	Chapter and verse
Jun Xiao, Zequn Zhang, Linquan Bai, Haishen Liang	Determination of the optimal installation site and capacity of battery energy storage system in distribution network integrated with distributed generation	IET Gener. Transm. Distrib., 2016, Vol. 10, Iss. 3, pp. 601-607
Mikaeel Ahmadi, Mohammed Elsayed Lotfy, Abdul Motin Howlader, Atsushi Yona, Tomonobu Senjyu	Centralised multi-objective integration of wind farm and battery energy storage system in real-distribution network considering environmental, technical and economic perspective	IET Gener. Transm. Distrib., 2019, Vol. 13, Iss. 22, pp. 5207-5217
Qingwu Gong, Yubo Wang, Jintao Fang, Hui Qiao, Dong Liu	Optimal configuration of the energy storage system in ADN considering energy storage operation strategy and dynamic characteristic	IET Gener. Transm. Distrib., 2020, Vol. 14, Iss. 6, pp. 1005-1011
Obinna Unigwe, Dahunsi Okekunle, Aristides Kiprakis	Smart coordination schemes for multiple battery energy storage systems for support in distribution networks with high penetration of photovoltaics	ET Gener. Transm. Distrib., 2019, Vol. 2, Iss. 3, pp. 347-354
Anh Thi Nguyen, Surachai Chaitusaney, Akihiko Yokoyama	Optimal strategies of siting, sizing, and scheduling of BESS: Voltage management solution for future LV network	IEEJ Transactions on Electrical and Electronic Engineering, 2019, Vol. 14, Iss. 5, pp. 694-704

Technical Reports on BESS Installation in MV/LV Distribution Grid (3)

Author	Title	Chapter and verse
Kohei Murakami, Shinya Yoshizawa, Hideo Ishii, Yasuhiro Hayashi, Hiroshi Kondo, Yuki Kanazawa, Hideo Nomura, Takuya Kajikawa	Dynamic Optimization of SVR Control Parameters for Improving Tap Operation Efficiency of Voltage Control in Distribution Networks	IEEJ Transactions on Electrical and Electronic Engineering,2021, Vol. 16, Iss. 1, pp. 67-77
Songpakit Kaewniyompanit, Hideharu Sugihara, Kiichiro Tsuji, Toshihisa Funabashi, Yoshimichi Okuno, Takanori Hayashi	Maximum potential of PV installation based on an energy system planning model considering a distribution voltage constraint	IEEJ Transactions on Electrical and Electronic Engineering, 2009, Vol. 4, Iss. 2, pp. 257-268
Ioannis Lampropoulos, Panagiotis Garoufalis, Paul P.J. van den Bosch, Wil L. Kling	Hierarchical predictive control scheme for distributed energy storage integrated with residential demand and photovoltaic generation	IET Gener. Transm. Distrib., 2015, Vol. 9, Iss. 15, pp. 2319-2327
Sachin Sharma, Khaleequr Rehman Niazi, Kusum Verma, Tanuj Rawat	Impact of battery energy storage, controllable load and network reconfiguration on contemporary distribution network under uncertain environment	IET Gener. Transm. Distrib., 2020, Vol. 14, Iss. 21, pp. 4719-4727
Riad Chedid, Ahmad Sawwas	Optimal placement and sizing of photovoltaics and battery storage in distribution networks	Energy Storage. 2019;1:e46. https://doi.org/10.1002/est2.46

Technical Reports on BESS Installation in MV/LV Distribution Grid (4)

Author	Title	Chapter and verse
Shohana Rahman Deeba, Rahul Sharma, Tapan Kumar Saha, Debraj Chakraborty, Andrew Thomas	Evaluation of technical and financial benefits of battery-based energy storage systems in distribution networks	IET Gener. Transm. Distrib., 2016, Vol. 10, Iss. 8, pp. 1149-1160
Mahfuz A. Shuvra, Badrul Chowdhury	Reconfigurable and flexible voltage control strategy using smart PV inverters with integrated energy storage for advanced distribution systems	IET Smart Grid, 2020, Vol. 3, Iss. 1, pp. 22-30
Bo Zhao, Caisheng Wang, Xuesong Zhang	Techniques for Mitigating Impacts of High-Penetration Photovoltaics	Grid-Integrated and Standalone Photovoltaic Distributed Generation Systems: Analysis, Design, and Control, 2017 https://doi.org/10.1002/9781119187349.ch9
Om Prakash Mahela, Baseem Khan, H. H. Alhelou, Sudeep Tanwar, Sanjeevikumar Padmanaban	Harmonic mitigation and power quality improvement in utility grid with solar energy penetration using distribution static compensator	IET Power Electron., 2021, 14:912–922. https://doi.org/10.1049/pel2.12074
Brendan Banfield, Duane A. Robinson, Ashish P. Agalgaonkar	Comparison of economic model predictive control and rule-based control for residential energy storage systems	IET Smart Grid, 2020, Vol. 3, Iss. 5, pp. 722-729

Abstract of Technical Report (1)
Economic viability for residential BESS in grid-connected PV plants

Today's residential battery energy storage systems (BESSs) are off the shelf products used to increase the self-consumption of residential photovoltaic (PV) plants and to reduce the losses related to energy transfer in distribution grids. This work investigates the economic viability of adding a BESS to a residential grid-connected PV plant by using a methodology for optimizing the size of the BESS. The identification of the optimal size which minimizes the total cost of the system is not trivial; indeed, it is a trade-off between OPEX and CAPEX, which are mainly affected by the battery technology, usage profile, expected lifetime, and efficiency. Here, an analysis of the opportunity to install a storage system together with a grid-connected residential PV plant is performed. Three typical low-voltage prosumers (Italy, Switzerland, and the UK) are investigated in order to take into account the different legislative and tariff framework over Europe. Numerical results reported here show that present costs of storages are still too high to allow an economic convenience of the storage installation. Moreover, an indication of the necessary incentives to allow the spreading of these systems is given.

Abstract of Technical Report (2)
Cost-benefit analysis of battery storage in medium-voltage distribution networks

The increasing deployment of non-dispatchable generation in electric systems where generation and demand must be balance d at all times has led to a renewed interest in technologies for energy storage. This study presents a cost–benefit analysis of energy storage for peak demand reduction in medium - voltage distribution networks. In particular, the installation of batteries in secondary substations is studied for three realistic large-scale networks representing urban, semi-urban and rural distribution areas. On the one hand, savings in energy costs derived from storing energy at low-priced hours and selling it at peak hours are considered. On the other hand, savings in network reinforcement due to the peak shaving are evaluated. Network reinforcement requirements are assessed using reference network models, large-scale network-planning tools often used by distribution regulators to establish the allowed distribution costs. Additionally, sensitivity to different demand growth ratios and battery capacities is analyzed. The final objective is to determine the target cost for batteries to be profitable from the point of view of distribution. Results show that significant savings can be obtained, especially in urban and semi-urban areas.

Abstract of Technical Report (3)
Optimal placement of battery energy storage in distribution networks considering conservation voltage reduction and stochastic load composition

Deployment of battery energy storage (BES) in active distribution networks (ADNs) can provide many benefits in terms of energy management and voltage regulation. In this study, a stochastic optimal BES planning method considering conservation voltage reduction (CVR) is proposed for ADN with high-level renewable energy resources. The proposed method aims to determine the optimal BES sizing and location to minimize the total investment and operation cost considering energy saving achieved by CVR, while satisfying system operational constraints in the presence of stochastic renewable power generation. The uncertainty of load composition is also modelled through scenario analysis. The proposed planning scheme is tested in a modified IEEE 15-bus system and 43-bus radial system, respectively. The numerical results validate that the combination of CVR and BES can achieve more energy savings.

Abstract of Technical Report (4)
Reliability-Based Sizing of Backup Storage

This letter describes an analytical approach to determining the size, in terms of both power and energy capacity, of a backup storage unit in such a way as to meet a specified reliability target. The backup could be in the form of electrical energy storage or fuel storage. The proposed approach might benefit facilities that require high levels of reliability in their electric supply.

Technical Report (5)
Quantifying the effects of medium voltage–low voltage distribution network constraints and distributed energy resource reactive power capabilities on aggregators

Distributed energy resources (DER), such as, photovoltaic systems and batteries, are becoming common among households. Although the main objective is reducing electricity imports (bills), they could also provide system-level services via an aggregator. However, the more DER provide services, the more important is ensuring that the corresponding operation does not result in network issues. To help DER aggregators understand the implications of network constraints, an AC optimal power flow-based methodology is proposed to quantify the effects that three-phase low voltage (LV) and medium voltage (MV) network constraints can have on the volume of services that can be provided for a given horizon, and the potential benefits from using DER reactive power capabilities. Using a convex multi-period formulation that avoids binary variables for batteries and incorporates voltage-dependent load models, the methodology maximizes DER exports (services) for service-related periods and household self-consumption for other periods (reducing bills). Different service periods are assessed to explore the extent of services throughout the day. Results using a realistic UK MV-LV network with 2400+ households, show that aggregator services can be highly overestimated when neglecting MV-LV network constraints, are influenced by voltage-demand load characteristics, and that exploiting DER reactive power capabilities can significantly unlock further services.

Technical Report (6)

Optimal planning of renewable energy source and energy storage in a medium- and low voltage distributed AC/DC system in China

As the quantity of DC load and distributed generation system increases in China, AC/DC distribution system is arousing more and more research interest for its high-efficiency distribution ability. In this study, the optimal size and location of renewable energy source (RES) and energy storage in a medium- and low-voltage distributed AC/DC system is studied. A modelling method for the optimisation of such hybrid AC/DC system is developed. The objective of the proposed optimization method is to minimise the life cycle cost of the system with consideration of the life span of RES. The planning method is based on energy balances and constraints of system operation. The utility requirements and subsidy in China for such system are also considered in the planning process. The method is demonstrated in a 10 kV and low-voltage distributed AC/DC system considering installing photovoltaic system, wind turbines, and electric storage system. The provided results indicate that the method is effective and applicable for the optimisation of the size and location of RES in distributed AC/DC system.

Abstract of Technical Report (7)

Determination of the optimal installation site and capacity of battery energy storage system in distribution network integrated with distributed generation

The presence of distributed generation (DG), represented by photovoltaic generation and wind generation, brings new challenges to distribution network operation. To accommodate the integration of DG, this study proposes a bi-level optimisation model to determine the optimal installation site and the optimal capacity of battery energy storage system (BESS) in distribution network. The outer optimisation determines the optimal site and capacity of BESS aiming at minimising total net present value (NPV) of the distribution network within the project life cycle. Then optimal power flow (OPF) and BESS capacity adjustment are implemented in the inner optimisation. OPF optimises the scheduling of BESS and network losses. On the basis of optimal scheduling of BESS, a novel capacity adjustment method is further proposed to achieve the optimal BESS capacity considering battery lifetime for minimising the NPV of BESS. Finally, the proposed method is performed on a modified IEEE 33-bus system and proven to be more effective comparing with an existing method without BESS capacity adjustment.

Abstract of Technical Report (8)

Centralised multi-objective integration of wind farm and battery energy storage system in real-distribution network considering environmental, technical and economic perspective

Integration of renewable energies such as wind and solar with an energy storage system (ESS) in a distribution network is the interest of current studies in power system engineering. Wind and battery ESS (BESS) are known for their complement and efficient approaches into the distribution networks. The promising of renewable energies for wind and solar in Afghanistan is a motivation for stepping up the power sector of the country by enhancing the power quality as well as self-dependency in electricity production. In this study, a multi-objective optimisation technique, non-dominated sorting genetic algorithm II (NSGA-II) is proposed for an extensive distribution network in Kabul city considering technical, environmental, and financial control schemes for the network improvement. Three different scenarios with various objective functions are deemed to evaluate their impact on decision variables and network parameters. Furthermore, optimum allocation of the wind turbine and charge/discharge scheduling of BESS are revealed with improvement in performance of the power system. Simulations are deployed in MATLAB® with its application on developed 162-bus real-distribution network to demonstrate the effect of different objective function arrangements in each scenario as well as confirming the robustness of the proposed approach.

Abstract of Technical Report (9)

Smart coordination schemes for multiple battery energy storage systems for support in distribution networks with high penetration of photovoltaics

The use of battery energy storage system (BESS) is one of the methods employed in solving the major challenge of overvoltage, experienced on distribution networks with high penetration of photovoltaics (PV). The overvoltage problem limits the penetration levels of PV into the distribution network, and the benefits that could be gained. This study presents three loosely-related schemes for the coordination of multiple BESSs in such networks. Through the efficient selection, coordination and timing of charge and discharge operations of the BESS, the scheme maintains bus voltages within statutory ranges during periods of high PV power generation and high network load demand. Network segmentation was used in two of the schemes to encourage more even utilisation of the BESS in order to maximise the economic benefits of the BESS. The algorithms for the schemes were implemented and demonstrated on two different distribution networks. Simulation results showed that the schemes met the objectives of mitigating overvoltage and more even cycling of the BESSs during their operating lifetimes.

Abstract of Technical Report (10)

Optimal configuration of the energy storage system in ADN considering energy storage operation strategy and dynamic characteristic

To meet the needs of energy storage system configuration with distributed power supply and its operation in the active distribution network (ADN), establish the dynamics of the all-vanadium redox flow battery energy storage system (BESS). On this basis, an energy storage operation of ADN strategy is proposed to stabilise the power fluctuation of the system. The energy storage configuration model with optimising objectives such as the fixed cost, operating cost, direct economic benefit and environmental benefit of the BESS in the life cycle of the energy is constructed, and the energy storage installation capacity, power and installation position are used as decision variables, which are solved by the dynamic programming algorithm. On the basis of case 33 and case 69 node examples and typical daily load and distributed generations output curve, the simulation analysis is carried out to obtain the optimal configuration result. At the same time, the system tie-line power and the dynamic characteristics of the energy storage system before and after the installation of the energy storage device are obtained. The simulation results show the validity of the model.

Abstract of Technical Report (11)

Optimal strategies of siting, sizing, and scheduling of BESS: Voltage management solution for future LV network

With the object of reducing CO_2 emission and the reliance on fossil fuels, solar power generation has received special support and is being deployed rapidly in many distribution networks. Battery energy storage system (BESS), an effective voltage management solution for low-voltage (LV) networks to deal with the high penetration of rooftop photovoltaic (PV) systems, is investigated in this paper considering the degradation of BESS due to aging. Two optimal strategies of BESS cost minimization are proposed for long-term planning and operation planning, where the utility is the BESS owner. As for the long-term planning, a strategy for siting and sizing of BESS is formulated based on the characteristics of the network, typical load, and PV generation profiles. Then, for the operation planning, schedules of BESSs and their cost estimation are provided based on the load and PV generation forecasts of 1 day ahead. The effectiveness of the proposed methods is demonstrated on the simplified network of the Metropolitan Electricity Authority, Thailand, using MATLAB (Natick, Mssachusetts, USA) 2016a and MATPOWER 6.0. © 2019 Institute of Electrical Engineers of Japan. Published by John Wiley & Sons, Inc.

Abstract of Technical Report (12)

Dynamic Optimization of SVR Control Parameters for Improving Tap Operation Efficiency of Voltage Control in Distribution Networks

In this study, we propose a new optimization method to determine the control parameters of a step voltage regulator (SVR) to maximize its voltage control characteristic in distribution networks (DNs) with photovoltaic systems. Considering the service life of an SVR, the proposed method evaluates the expected number of tap operations and the voltage control performance based on the past voltage measurements obtained with sensors in the DN. Subsequently, the time series of two control parameters, that is, the reference voltage and the dead bandwidth, are determined for the most improved voltage control characteristic of the SVR, maintaining the number of tap operations within the upper limit. Voltage control simulation using a realistic 6.6-kV DN model is conducted to show that the proposed method significantly reduces the voltage violation compared with the conventional SVR control using fixed parameters, as well as the alternative SVR operation developed in our previous study, in which the reference voltage was temporally updated. In addition, the simulation results demonstrate that the proposed method realizes efficient tap operations to mitigate the voltage violation, whereas the conventional method requires a much larger number of tap operations to mitigate the voltage violation to the same degree. © 2020 Institute of Electrical Engineers of Japan. Published by Wiley Periodicals LLC.

Abstract of Technical Report (13)

Maximum potential of PV installation based on an energy system planning model considering a distribution voltage constraint

As the key solution for energy sustainability this decade, the growth of installing photovoltaic (PV) systems has dramatically increased. However, the high penetration of PV systems can cause a voltage variation problem in a distribution grid. This paper proposes a model for evaluating the maximum potential for installing PV systems in an urban area under a bus voltage constraint. A PV system is considered as an energy system alternative that replaces a conventional system. Regarding the power variation, it is necessary to add a parameter that is used to evaluate the variation of PV systems in terms of a standard deviation to the PV systems' electric load curve. The installations of PV and conventional systems are determined as share solutions for each load area along a distribution network. Total power loads and variations in each load area are input to a load flow calculation to obtain each bus voltage and confirm the voltage constraint. Finally, the total PV system installations over the whole network area is maximized. The alternative PV system with battery installation is introduced to validate the model evaluation when comparing with a typical PV system without a battery, which has larger power variation. Furthermore, adjusting the sending voltage at a substation to increase the PV installation is validated using the proposed model. Copyright © 2009 Institute of Electrical Engineers of Japan. Published by John Wiley & Sons, Inc.

Abstract of Technical Report (14)

Hierarchical predictive control scheme for distributed energy storage integrated with residential demand and photovoltaic generation

CHUBU Electric Power
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A hierarchical control scheme is defined for the energy management of a battery energy storage system which is integrated in a low-voltage distribution grid with residential customers and photovoltaic installations. The scope is the economic optimisation of the integrated system by employing predictive control techniques. The approach is based on hierarchical decomposition of the optimisation problem in the time domain by composing a three-level scheduling and control scheme, that is, day-ahead, intra-hour, and real-time, where the initial and final states of each sub-problem are chosen as coordination parameters. The day-ahead and the intra-hour problems address the interactions with electricity markets during the scheduling phase. The real-time algorithm is able to adapt the operation of the battery system according to updated information about market conditions, residential demand, and local generation, and subject to the network capacity and other technical constraints. The simulation scenarios address the interactions with the day-ahead auction and the imbalance settlement system in the Netherlands.

Abstract of Technical Report (15)

Impact of battery energy storage, controllable load and network reconfiguration on contemporary distribution network under uncertain environment

CHUBU Electric Power
NIPPON KOEI

The design of future distribution systems involves the application of flexible technologies such as renewable-based distributed generations (DGs), battery energy storage systems (BESSs), demand response for controllable load management and distribution network reconfiguration for achieving assets optimisation and for improving the efficiency of the distribution systems. The renewable-based DGs are the source of uncertainty that can be overcome by the proper modelling of renewable resources and application of energy storage devices. However, the coordination of these flexible technologies is essential to avoid counterproductive results and to extract maximum possible benefits from these technologies. This work, therefore, aims to study the coordinated impact of controllable load with renewable-based DGs, BESSs and network reconfiguration for improving the performance of distribution systems. The coordination of these technologies is a very complex optimisation problem due to various constraints associated with charging and discharging of BESSs, complex nature of controllable load management and feeder current limits of distribution network. In this study, an improved water evaporation optimisation algorithm is developed to solve this multi-constraint complex optimisation problem to minimise the network loss and voltage profile improvement for distribution system. The results show that this coordinated operational problem significantly improves the performance of distribution systems.

Abstract of Technical Report (16)

Optimal placement and sizing of photovoltaics and battery storage in distribution networks

A two-step optimization approach is proposed to study the effects of adding a battery energy storage system (BESS) to a distribution network incorporating renewable energy sources. In this article, the first step finds the optimal size and placement of the photovoltaic (PV) arrays that lead to the lowest possible losses, cost and voltage deviation from the reference bus, while the second step starts by performing another optimization in order to find the optimal size and placement of the BESS that lead to a further reduction in the same objectives. The optimized Grid-PV and Grid-PV-BESS configurations are subjected to a time domain power flow so that the annual energy losses and voltage profile of each bus can be observed. The article provides a novel formulation that treats the problem as a multi-objective optimization and uses the Genetic Algorithm technique to reach optimal configuration in both steps. An Institute of Electrical and Electronic Engineers 13-Bus test feeder is used to demonstrate the usefulness of the proposed technique.

Abstract of Technical Report (17)

Evaluation of technical and financial benefits of battery-based energy storage systems in distribution networks

Prompted by technical issues that have arisen due to the widespread deployment of distributed intermittent renewable generators, rapidly rising peak demand and reductions in battery price, the use of battery-based energy storage systems in power networks is on the rise. While battery-based energy storage has the potential to deliver technical benefits, the best possible sizing, location and usage govern the financial viability. The objective of this study is twofold. Firstly, a generalised approach is proposed to model network upgrade deferral as a function of load growth rate, renewable generation penetration and peak shave fraction. This model is then used for the formulation of an optimisation problem which benefits from multi-period power flow analysis to co-optimise battery size, location, charge/discharge profile for a pre-specified number of units to be deployed in a given distribution network. The proposed approach is implemented using the generic algebraic modelling system platform and validated on an Australian medium voltage distribution network under multiple practical and potential future scenarios.

Abstract of Technical Report (18)

Reconfigurable and flexible voltage control strategy using smart PV inverters with integrated energy storage for advanced distribution systems

A novel circuit topology is proposed for utility-owned photovoltaic (PV) inverters with integrated battery energy storage system (BESS) and compared to two state-of-the-art configurations. The proposed topology offers flexibility and can be applied to a range of distribution networks for tight voltage regulation. During BESS maintenance, the solar-storage system reconfigures itself for a self-run mode of operation, and actively compensates high penetration induced voltage fluctuation without activating overcurrent protection of the inverter, which is an added advantage of this strategy. This advantage is achieved by slightly increasing the inverter size to reserve a portion of inverter's current-carrying capability. A dynamic model of the new configuration is also developed to analyse its performance in providing fast response for high ramp up/down solar irradiance variation. As the proposed control strategy is implemented at the device level, the local voltage regulation is quite guaranteed to be in the permissible range. Results from the analysis performed on a modified IEEE 33 bus medium voltage distribution network with multiple inverters show evidence that the proposed strategy has the potential to mitigate voltage fluctuation in several extreme cases.

Abstract of Technical Report (19)

Techniques for Mitigating Impacts of High-Penetration Photovoltaics

This chapter focuses on the application of energy storage technologies, demand response, and an advanced strategy for cluster partition control for integrating high-penetration distributed photovoltaics (PVs) into the distribution network. From the energy conversion point of view, the electrical energy storage technologies can be categorized into mechanical energy storage, electromagnetic energy storage, phase-change energy storage, and chemical energy storage. At present, the energy storage technology widely used in the power system is the electrochemical energy storage approach, including lead-acid battery, Lithium-ion battery, and flow cell. Some commonly used mathematical models are developed for electrochemical energy storage batteries and analyzes how the energy storage system improved the PV accommodation capacity of the distribution network by taking the lead-carbon battery as an example. In general, network partition-based zonal voltage control of a distribution network with PVs includes two processes: community-partition-based cluster optimization and PV active and reactive power-voltage optimization control in each sub-network.

Abstract of Technical Report (20)

Harmonic mitigation and power quality improvement in utility grid with solar energy penetration using distribution static compensator

Distribution static compensator is based on power electronic devices technology which is utilized to supply rapid changes in active power as well as reactive power of utility grids. This is useful to achieve corrections in power factor, balancing of load, compensation of current and filtering of harmonics. Therefore, proposed work investigates the improvement of the power quality by utilizing the distribution static compensator, which is equipped by battery energy storage system and interfaced to distribution network with solar photo voltaic (PV) energy integration. In the present study, distribution static compensator is controlled using a control strategy based on the synchronous reference frame theory. Customised IEEE-13 nodes test system incorporating solar PV generation and distribution static compensator, is utilized to perform the harmonic mitigation and power quality analysis. Disturbances of power quality and harmonics have been investigated due to abrupt changes in the insolation of solar radiation, outage of PV plant from grid and synchronization of PV plant to grid. MATLAB/Simulink environment is utilized to perform the study. Effectiveness of a developed approach is validated by comparing results of simulation with results extracted in real time using real time digital simulator. Results indicate that the developed method is more effective for harmonic mitigation and improving power quality of electrical power in distribution network integrated with solar PV generation. Performance of the approach is compared with the performance of methods reported in the literature to establish the suitability of the method for harmonics mitigation and power quality improvement in grid with solar energy.

Abstract of Technical Report (21)

Comparison of economic model predictive control and rule-based control for residential energy storage systems

This study quantifies the benefits of implementing model predictive control on residential solar PV and energy storage systems considering a time-of-use demand tariff, feed-in tariff and varying PV system sizes and battery life-cycle costs. The control system analysed makes use of economic model predictive control (EMPC) whereby the objective function is directly tied to the economics of the system. Using residential load and PV data from an Australian distribution network service provider, the EMPC controller is compared to a rule-based controller, highlighting the benefits of EMPC in regards to annual economic performance and battery energy throughput. The EMPC algorithm is then tested using 10 residential customers at the low voltage feeder level showing the capacity for the EMPC controller to shift peak demand and flatten the aggregated load profile of 30 residential customers.

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Importance of Technical Measurement Capability Due to Mass VRE Introduction

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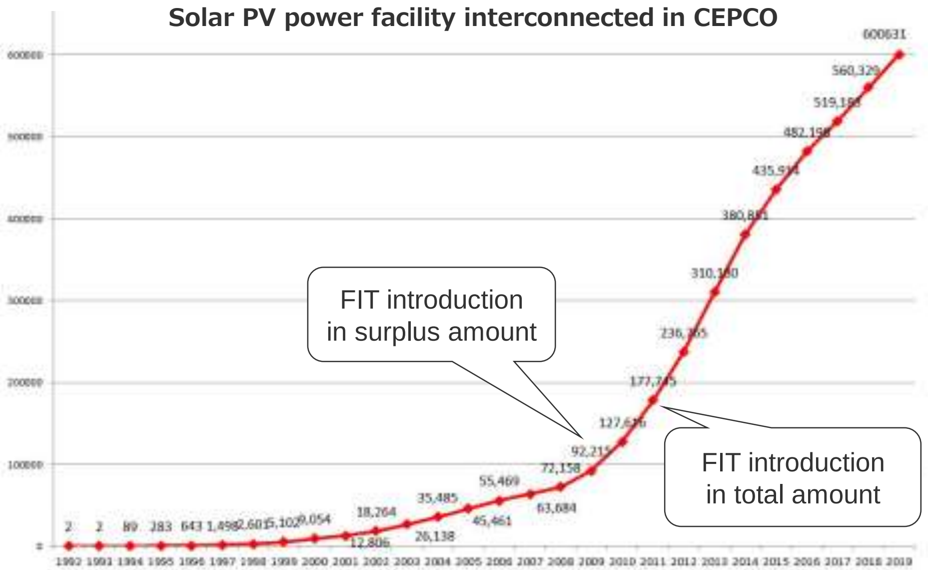
Trend of Solar PV Introduction



Inquiry on Solar PV Generation

What are the situations where it is easy to make lots of inquiries on output power limitation of solar PV generation?

Consumer's matter	Electric power co.'s matter
• Matter of consumer's facility side • Unproper setting of AVR, etc.	• Insufficient voltage management (Higher voltage, etc.)

Challenging

100% optimization of AVR set value for solar PV generation (total amount)	Reviewing and optimizing outgoing voltage at a substation and an SVR

Achievements by cooperation between measurement stuff and maintenance stuff in both branch offices and sales offices

Necessary of Technical Capability in Measurement

Occurrences of solar PV output power limitation is getting fewer gradually.
Nevertheless, measuring technology is more and more required in the future.
Because…

At present

Consumer	Electric power co.
Widespread of saving energy, creative energy such as RE and BSS.	Application of smart meter, Sensing of advance distribution facility
Taking more and more interest in electricity.	Voltage which has not been seen sensitively will be exposed to view.

In future

Customer explanation ability and "diversification / sophistication" of measurement work are presumed. It is necessary to improve the technical measurement capability.

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Technical Measurement Capabilities

Concrete contents in technical measurement capability

Tech-level	Item	Content
Senior	• Harmonic • Instantaneous voltage fluctuation • Voltage flicker • Transient phenomenon	・ Measuring instruments and measurement points (including the required number) suitable for the event that occurs can be selected. ・ The cause can be identified by analyzing the measurement results. ・ Cooperate with related departments to plan countermeasures in consideration of costs. ・ After coordinating with related departments, we can explain to customers who offer and customers who are the source.
Middle	• Suppression of PV power generation output • Appropriate voltage deviation (including those caused by Ferranti effect and voltage imbalance) • Annual power quality report	・ Measuring instruments and measurement points (including the required number) suitable for the event that occurs can be selected. ・ Analysis of measurement results can identify the cause (customer / our low-voltage system / our high-voltage system). ・ Cooperate with related departments to plan countermeasures in consideration of costs. ・ Can explain to customers.
Beginner	• Suppression of PV power generation output • Appropriate voltage deviation • Annual voltage measurement report	・ Measuring instruments and measurement points (including the required number) suitable for the event that occurs can be selected. ・ Measurement can be set, measurement, and measurement data can be extracted independently, and the correctness of measurement results can be judged. ・ Measurement results can be analyzed and the cause can be isolated (customer side / our company side). ・ It is possible to formulate countermeasures (including reviewing the set value of the automatic voltage regulator for photovoltaic power generation) when the cause is on the customer side. ・ Can explain to customers.

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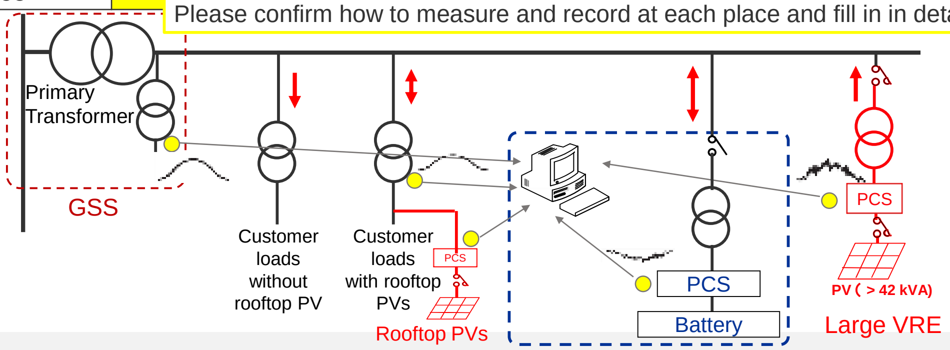
Measurement to Record Output Power/Voltage Data

(1) How to Measure Output Power/Voltage Data

Measurement	Substation	VRE interconnection	Feeder end, etc.
DD1	• Measurement is possible with the customers PV data at connection point, as CEB is commissioning PV installation under this condition. • Can be calculated from the metering data, as low voltage is recorded in meter register.		
DD2	• Measurement is possible by installing a energy meter at PV Installation.		
DD3	• Measurement is possible by installing a measuring instrument on customer equipment. • Soft data can be saved by recorder. ・Some data are recorded.		
DD4	• Measurement is possible by installing a measuring instrument on customer equipment.		
LECO			

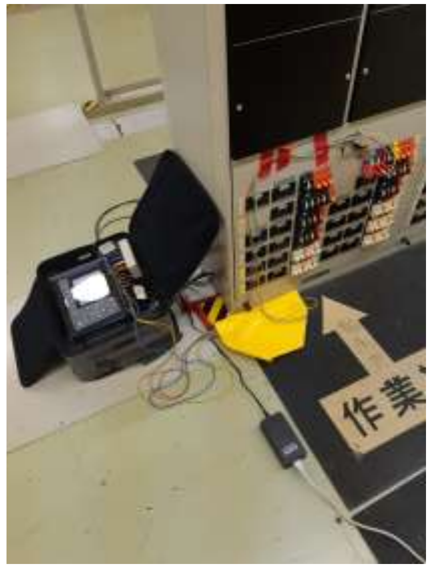
Please confirm how to measure and record at each place and fill in in detail.



Types of Measuring Instrument

General purpose products	電源ラインモニター	ｸﾗﾝﾌﾟｵﾝﾊﾟﾜｰﾊｲﾃｽﾀ	電源品質アナライザ	クランプオンパワーロガー
				
		Medium series		Beginner series

Image of Measuring at a Substation



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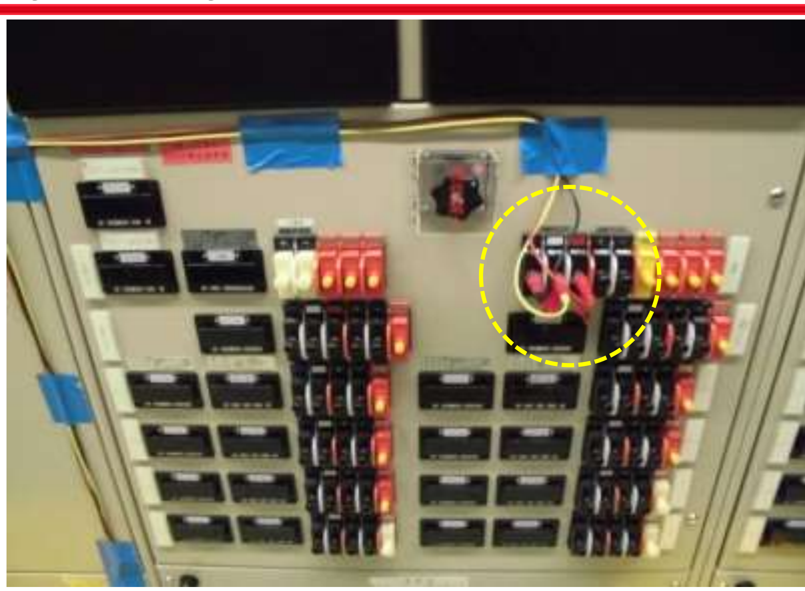
Voltage Measuring in Front of Panel at Substation



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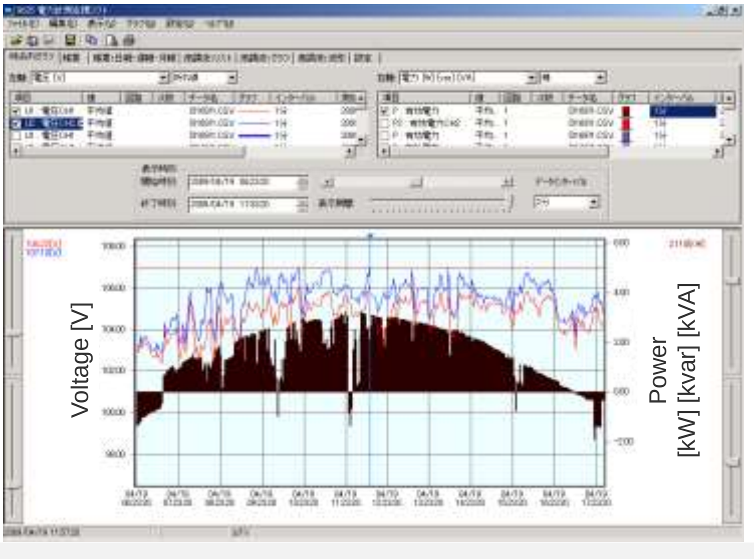
Measuring Point in Back of Panel at Substation

Analyzing Software



Analyzing Software

Procurement of Measuring Instrument

Portable Power Loggers for Energy Audits and Energy Conservation

Key Features

- Supports single to three-phase, 4-wire circuits
- Measure between 90V to 780V
- Simultaneously measure up to three single-phase, 2-wire circuits (in the same power system)
- Slim, compact design that can be placed anywhere
- Store months of data on SD cards
- The QUICK SET function guides you in making the right connections
- Choose PW3360-21 for harmonic measurements up to the 40th order

Procurement of Measuring Instrument

Portable Power Loggers for Energy Audits and Energy Conservation

Navigate clamp-on power logger operation with graphical, easy-to-use displays of wiring procedures

The PW3360's QUICK SET feature is an on-screen guide that walks you through the setup process, right up to starting measurement. Even if you're unaccustomed to how clamp-on power loggers work, you'll be able to easily configure and connect the instrument for 3-phase power measurement. In addition, by alerting you to any wiring mistakes, the device's "wiring check" function serves to prevent measurement errors that are caused by undetected wiring mistakes.

Procurement of Measuring Instrument

Portable Power Loggers for Energy Audits and Energy Conservation

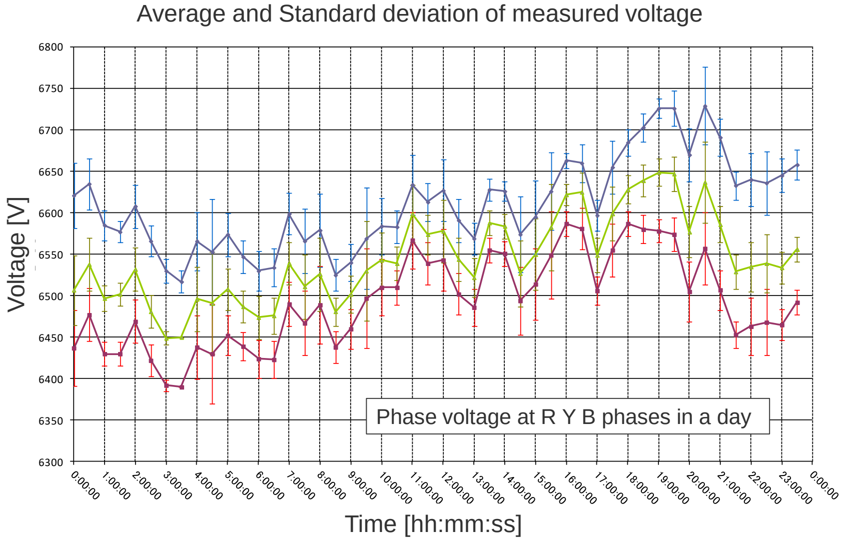
Power logger functionality for displaying measurement results as a graph so you can review them at a glance

The PW3360 displays recorded measured values as a graph for convenient use in power management. In addition to instantaneous measured values, you can review maximum, minimum, and average values by moving the cursor on the demand and trend graph displays.

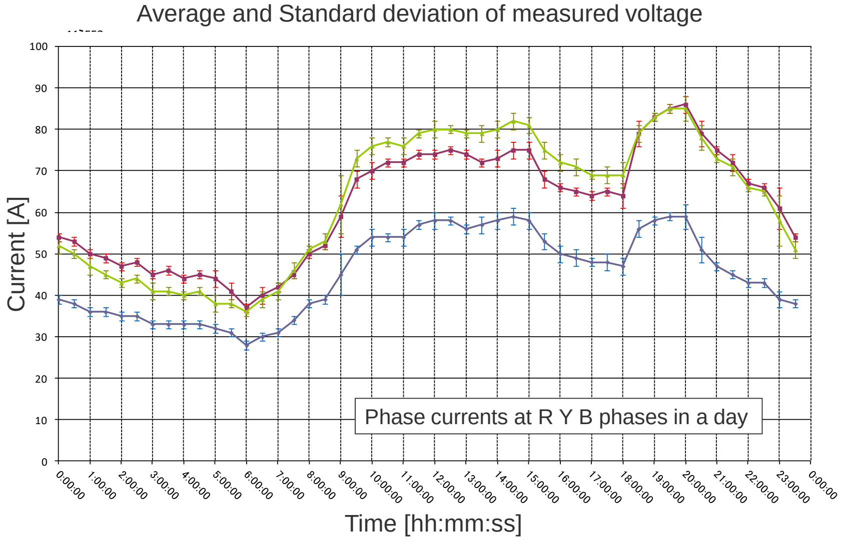
Specifications of Measuring Instrument

Measurement line & number of circuits	50/60 Hz, Single phase 2 wires (1/2/3 circuits), Single phase 3 wires (1 circuit), Three phases 3 wires (1 circuit), Three phases 4 wires (1 circuit), Current only: 1 to 3 channels
Measurement items	Voltage RMS, current RMS, voltage fundamental wave value, current fundamental wave value, voltage fundamental wave phase angle, current fundamental wave phase angle, frequency (U1), voltage waveform peak (absolute value), current waveform peak (absolute value), active power, reactive power (with lag/lead display), apparent power, power factor (with lag/lead display) or displacement power factor (with lag/lead display), active energy (consumption, regeneration), reactive energy (lag, lead), energy cost display, active power demand quantity (consumption, regeneration), reactive power demand quantity (lag, lead), active power demand value (consumption, regeneration), reactive power demand value (lag, lead), power factor demand, pulse input [PW3360-21 only]: Harmonic voltage level, harmonic current level, harmonic power level, content percentage, phase angle, total harmonic distortion (THD-F or THD-R), up to 40th order
Voltage ranges	600 V AC (Effective measurement range: 90.00 V to 780.00 V)
Current ranges	500.00 mA to 5.0000 kA AC (depends on current sensor in use), 50.000 mA to 5.0000 A AC (Leak clamp on sensor only)
Power ranges	300.00 W to 9.0000 MW (depends on voltage/current combination and measured line type)
Basic accuracy	Voltage : ±0.3% rdg. ±0.1% f.s Current : ±0.3% rdg. ±0.1% f.s. + clamp sensor accuracy Active power : ±0.3% rdg. ±0.1% f.s. + clamp sensor accuracy (at power factor = 1)
Display update rate	0.5 sec (except when accessing SD card or internal memory, or during LAN/USB communication)
Save destination	SD memory card, or internal memory at real time
Data save interval	1 sec to 30 sec, 1 minute to 60 minutes, 14 selections
Save items	Measurement value save: Average only / Average, Max./Min. value, [PW3360-21 only]: Harmonic data save: Average only / average, max./min. value in binary format, Screen copy: BMP form (saved every 5 min. at minimum interval time), Waveform save: Binary waveform data
Interfaces	SD/SDHC memory card LAN 100BASE-TX: HTTP server function USB 2.0: When connected to a PC, the SD Card and internal memory are recognized as removable storage devices, remote settings via communication program, data download Pulse output: proportional to active power consumption when measuring integral power consumption, Isolated open-collector signal
Functions	Connection check, Quick Set navigation guide, clock, pulse input
Power supply	AC Adapter Z1006: (100 to 240 V AC, 50/60 Hz), 40 VA (including AC adapter) Battery Pack 9459: (DC 7.2 V, 3 VA, charging time 6 hr 10 m), 8 hours of continuous use (with back light off)
Dimensions and mass	180 mm (7.09 in) W × 100 mm (3.94 in) H × 48 mm (1.89 in) D, 550 g (19.4 oz) without PW9002 180 mm (7.09 in) W × 100 mm (3.94 in) H × 67.2 mm (2.65 in) D, 830 g (29.3 oz) with PW9002
Accessories	Voltage cord L9438-53 ×1 set, AC adapter Z1006 ×1, USB cable ×1, Instruction manual ×1, Measurement guide ×1, Color clip ×1 set: red, yellow, blue, white/two each, for color-coding clamp sensors, Spiral tubes for grouping clamp sensor cords ×5

Measured and Recorded Voltage Data Sample



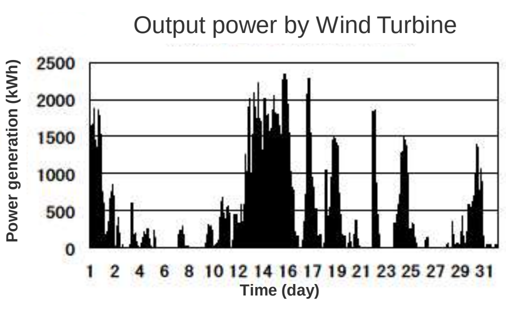
Measured and Recorded Power(Current) Data Sample

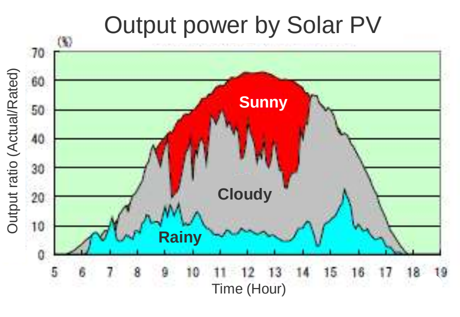


Fluctuation of Output power by PV/WT

Output power generated by PV and wind turbine is not stable due to the weather conditions such as wind conditions and solar radiation conditions.

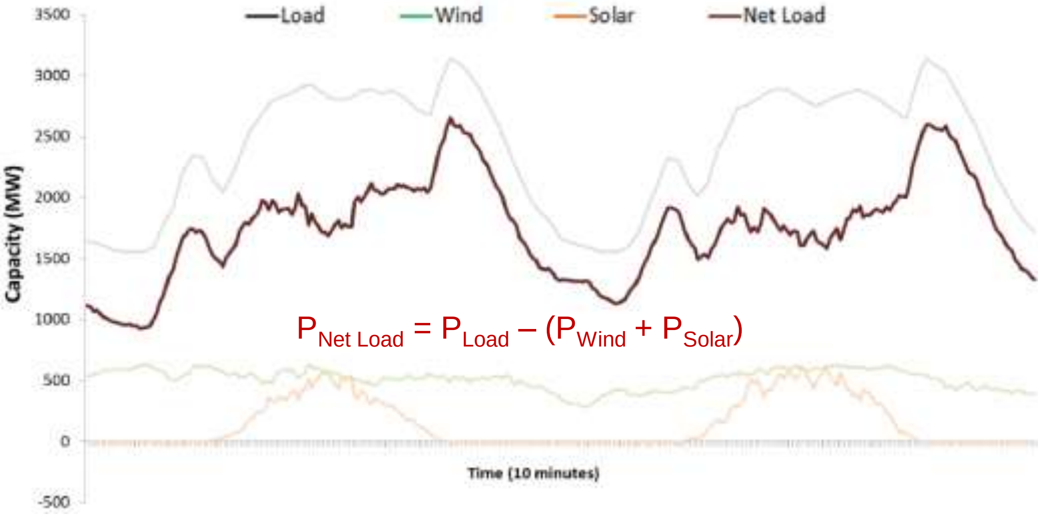
In addition, there is no supply and demand adjustment function for solar and wind power, and it is not possible to adjust the output according to demand.





Each generation curve of sunny, cloudy and rainy days is helpful to analyze solar PV generation.

Load Curve with Wind and Solar PV Generation

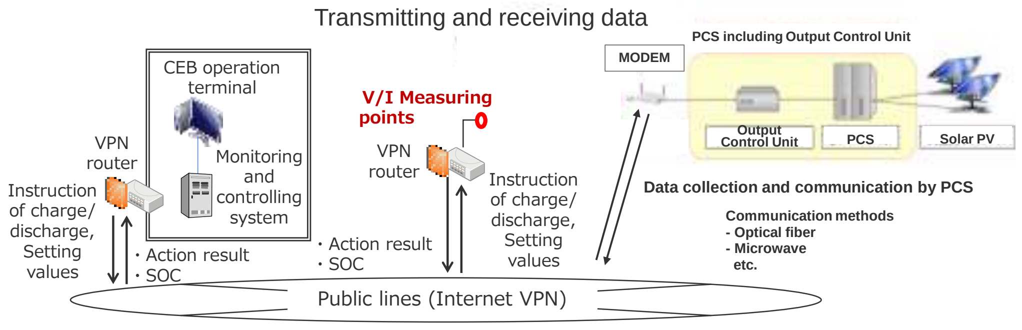


$$P_{Net\ Load} = P_{Load} - (P_{Wind} + P_{Solar})$$

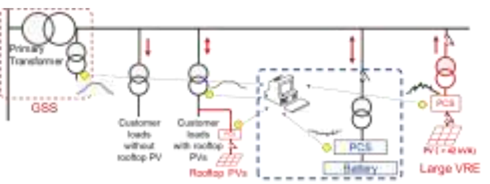
Each load curve of weekday and weekend is helpful to analyze load fluctuation.

How to Acquire Output Power/Voltage Data (How to Measure and Communicate)

How to Collect Measured Output Power/Voltage Data



	Data Communication method
DD1	
DD2	
DD3	
DD4	
LECO	



Please check how to send data and fill in in detail.

(Ref.) Function of Smart Meter in Japan

[Structure (Image) of a smart meter]
(1-phase 3-wire type)

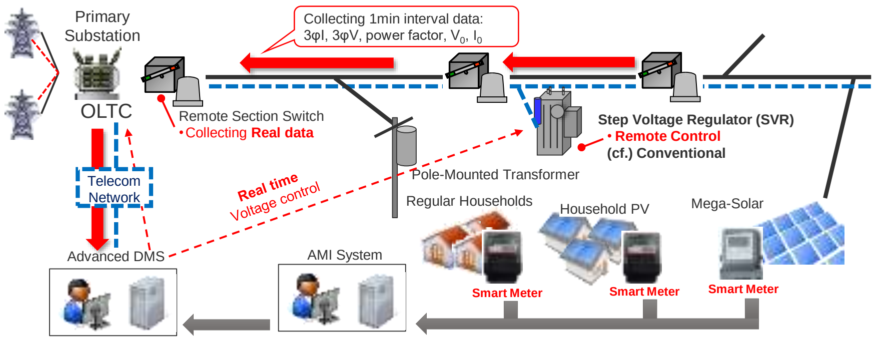
Functions of a smart meter

Metering	・**Collecting and memorizing the counting figure every 30 minutes (able to memorize the data of 44 days or more)** ・**Metering electric power both in forward direction and reverse direction (2 directions measurement)**
Switching on/off	・Switching on–off with inner switch which is installed inside the measuring part ・Limiting the current (function as current limiting breaker)
Communication	・**Transmitting and receiving data**
Measurement	・**Collecting and memorizing the average voltage every 30 minutes (able to memorize the data of 30 hours or more)** ・**Responding 3 second average value based on the measurement of voltage, current and power every one second in case of receiving the request for measurement through communication line**
Detecting	・Detecting and memorizing events such as de-energized / re-energized, voltage drop and opening / closing operation of terminal cover (able to memorize the data of 40 events)

(Ref) State-Grasping Method of Distribution Grid for Future

Upgrading for state-grasping method to improve accuracy of power flow calculation of distribution grid

- Apply sensor-equipped section switch to measure real-time current and voltage of major lines
- Sum up smart meter data for grasping PV output and to estimate current of branch lines.



Priority of VRE Matters for a Pilot Project

Matters by Mass PVs Introduction

Division	Province	District	Before Soorya Bala Sangramaya			After Soorya Bala Sangramaya (2016-09-06)								
			Net Metering			Net Metering			Net Accounting			Net Plus		
			No of Consumers	Unit capacity (kW/cons.)	Capacity (KW)	No of Consumers	Unit capacity (kW/cons.)	Capacity (KW)	No of Consumers	Unit capacity (kW/cons.)	Capacity (KW)	No of Consumers	Unit capacity (kW/cons.)	Capacity (KW)
DD1	North Western	Kurunegala	111	4.3	482	104	4.8	495	168	5.5	920	24	53	1,276
		Puttalam	101	4.6	461	127	5.8	738	180	5.4	964	3	89	268
		Total	**212**	**4.4**	**943**	**231**	**5.3**	**1,233**	**348**	**5.4**	**1,884**	**27**	**57**	**1,544**
	North Central	Anuradhapura	41	9.7	396	53	8.0	423	84	9.7	815	25	22	560
		Polonnaruwa	38	4.8	181	37	5.7	209	33	8.6	283	2	2	4
		Total	**79**	**7.3**	**577**	**90**	**7.0**	**632**	**117**	**9.4**	**1,098**	**27**	**21**	**563**
	Northern	Jaffna	146	4.1	596	138	4.5	624	340	4.7	1,599	33	7	238
		Kilinochchi	9	17.4	157	4	21.3	85	8	2.8	22	3	284	853
		Mullaitivu	2	6.9	14	4	7.9	31	2	17.0	34	1	350	350
		Vavuniya	5	2.2	11	9	10.3	93	12	3.9	47	2	13	26
		Mannar	6	3.3	20	6	3.7	22	4	1.8	7	2	40	79
		Total	**168**	**4.7**	**798**	**161**	**5.3**	**855**	**366**	**4.7**	**1,709**	**41**	**38**	**1,546**
	Colombo City	**Colombo**	**1,402**	8.2	**11,500**	**714**	10.0	**7,139**	**160**	8.3	**1,321**	**17**	80.5	**1,368**
	DD1 Total		**1,861**	7.4	**13,819**	**1,196**	8.2	**9,860**	**991**	6.1	**6,013**	**112**	44.8	**5,020**
DD2	Eastern	Batticaloa	17	6.2	106	10	6.9	69	0	#DIV/0!	0	1	1,650.0	1,650
		Ampara	26	6.0	155	63	5.2	326	15	8.7	130	2	505.0	1,010
		Trincomalee	8	13.1	105	16	9.7	155	3	6.4	19	2	51.5	103
		Total	**51**	**7.2**	**366**	**89**	**6.2**	**550**	**18**	**8.3**	**149**	**5**	**552.6**	**2,763**
	Central	Nuwa Eliya	8	32.3	259	4	8.2	33	1	16.2	16	0	#DIV/0!	0
		Kandy	167	4.6	767	125	9.6	1,203	81	6.2	506	20	74.4	1,489
		Matale	16	8.0	128	11	38.4	422	30	10.9	326	2	71.0	142
		Kegalle	34	29.0	985	81	84.7	6,862	34	7.8	265	6	47.8	287
		Total	**225**	**9.5**	**2,139**	**221**	**38.6**	**8,521**	**146**	**7.6**	**1,113**	**28**	**68.5**	**1,918**
	WPN	**Gampaha**	**613**	6.5	**3,989**	**540**	4.8	**2,570**	**670**	4.6	**3,074**	**36**	190.4	**6,856**
	DD2 Total		**889**	7.3	**6,494**	**850**	13.7	**11,641**	**834**	5.2	**4,336**	**69**	167.2	**11,537**
DD3	Sabaragamuwa	Rathnapura	46	7.3	337	99	9.3	918	119	5.7	673	28	87.0	2,437
		Kegalle	5	3.8	19	55	3.3	181	23	5.9	136	7	59.5	417
		Total	**51**	**7.0**	**356**	**154**	**7.1**	**1,099**	**142**	**5.7**	**809**	**35**	**81.5**	**2,854**
	Uva	Badulla	18	7.9	142	58	8.2	476	28	4.9	138	3	166.3	499
		Monaragala	5	14.4	72	51	8.3	423	11	13.0	144	6	93.1	558
		Total	**23**	**9.3**	**214**	**109**	**8.2**	**899**	**39**	**7.2**	**282**	**9**	**117.5**	**1,057**
	WPS II	Colombo	811	3.2	2,599	1,303	6.1	8,000	481	6.8	3,267	52	107.5	5,590
		Kalutara	55	3.4	187	168	9.2	1,542	80	5.3	423	13	153.2	1,991
		Total	**866**	**3.2**	**2,786**	**1,471**	**6.5**	**9,541**	**561**	**6.6**	**3,691**	**65**	**116.6**	**7,581**
	DD3 Total		**940**	3.6	**3,356**	**1,734**	6.7	**11,540**	**742**	6.4	**4,781**	**109**	105.4	**11,493**
DD4	Southern	Galle	71	7.8	555	76	9.7	740	60	8.0	483	4	33.5	134
		Matara	106	8.0	849	191	11.7	2,227	252	9.4	2,359	23	186.9	4,298
		Hambantota	38	13.6	515	78	7.8	608	82	10.6	871	13	70.1	911
		Total	**215**	**8.9**	**1,919**	**345**	**10.4**	**3,576**	**394**	**9.4**	**3,713**	**40**	**133.6**	**5,342**
	WPS I	Colombo	732	4.6	3,342	614	8.0	4,926	311	5.7	1,761	14	222.2	3,110
		Kalutara	30	4.2	127	49	8.2	402	37	5.6	206	6	121.5	729
		Total	**762**	**4.6**	**3,469**	**663**	**8.0**	**5,328**	**348**	**5.7**	**1,967**	**20**	**192.0**	**3,839**
	DD4 Total		**977**	5.5	**5,388**	**1,008**	8.8	**8,903**	**742**	7.7	**5,681**	**60**	153.0	**9,182**
CEB Total			**4,667**	6.2	**29,057**	**4,788**	8.8	**41,944**	**3,309**	6.3	**20,811**	**350**	106.4	**37,231**

	Total consumers	Total capacity (kW)
Total (Before Sooryabala Sangramaya)	4,667	29,057
Total (After Sooryabala Sangramaya)	8,447	99,986
Increasing ratio	181%	344%
Total	13,114	129,043

All types and capacities of PVs are included?

Which areas and feeders have higher priority matters?

Matters by Mass VRE introduction

	DD1	DD2	DD3	DD4	LECO
Voltage fluctuation					
High voltage					
Low voltage					
Harmonics					
Protection coordination					
Reverse power overloading					
Facility Overloading					
High loss					
Phase unbalance					
Low reliability					
Low flexibility					
Intermittency					
Islanding					

What are the matters by mass VRE introduction?

Target of Supply Reliability

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- Supply reliability
  - Important load
  - Urban/Rural
  - SS, Feeder, etc.

Index	Norm
SAIDI	To be determined by PUCSL?
SAIFI	To be determined by PUCSL?
CAIDI	To be determined by PUCSL?

- Voltage drop
  - 33/36 kV
  - 11/12 kV
  - 230/400 V

Classification	Normal	Contingency
33/36 kV	-6% ~ +6%	-10% ~ +10%
11/12 kV	-6% ~ +6%	-10% ~ +10%
230/400 V	-6% ~ +6%	-10% ~ +10%

- Replacement due to overload

Facility	Loading rate criteria
Distribution line	70% for economy 125% for emergency
Distribution substation	80% for normal ?% for emergency
Primary substation	125% for overloading

VRE Matter Information in MV Distribution Lines

CHUBU Electric Power / NIPPON KOEI

Division	Province	District	PSS Voltage (kV)	PSS	Feeder	High reliability (special customer, high-tech,	Total length (km)	Before Soorya Bala Sangramaya (2016-09-06) Net Metering No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	After Soorya Bala Sangramaya Net Metering No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	Net Accounting No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	Net Plus No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	Forward max. (MW)	Reverse min. (MW)	Overload part [km, %,	Voltage max. (kV)	min. (kV)	Load factor	fluctuation (%,Hz)	Harmonic degree r
DD1	North Western	Kurunegala	33/11		01			111	4.3	482	104	4.8	495	168	5.5	920	24	53	1,276								
					02																						
					03																						
			132/33		01																						
					02																						
					03																						
		Puttalam						101	4.6	461	127	5.8	738	180	5.4	964	3	89	268								
		Total						**212**	**4.4**	**943**	**231**	**5.3**	**1,233**	**348**	**5.4**	**1,884**	**27**	**57**	**1,544**								
	North Central	Anuradhapura						41	9.7	396	53	8.0	423	84	9.7	815	25	22	560								
		Polonnaruwa						38	4.8	181	37	5.7	209	33	8.6	283	2	2	4								
		Total						**79**	**7.3**	**577**	**90**	**7.0**	**632**	**117**	**9.4**	**1,098**	**27**	**21**	**563**								
	Northern	Jaffna						146	4.1	596	138	4.5	624	340	4.7	1,599	33	7	238								
		Kilinochchi						9	17.4	157	4	21.3	85	8	2.8	22	3	284	853								
		Mullaitivu						2	6.9	14	4	7.9	31	2	17.0	34	1	350	350								
		Vavuniya						5	2.2	11	9	10.3	93	12	3.9	47	2	13	26								
		Mannar						6	3.3	20	6	3.7	22	4	1.8	7	2	40	79								
		Total						**168**	**4.7**	**798**	**161**	**5.3**	**855**	**366**	**4.7**	**1,709**	**41**	**38**	**1,546**								
	Colombo City	**Colombo**						**1,402**	8.2	**11,500**	**714**	10.0	**7,139**	**160**	8.3	**1,321**	**17**	80.5	**1,368**								
DD1 Total								**1,861**	**7.4**	**13,819**	**1,196**	**8.2**	**9,860**	**991**	**6.1**	**6,013**	**112**	**44.8**	**5,020**								
DD2	Eastern	Batticaloa						17	6.2	106	10	6.9	69	0	#DIV/0!	0	1	1,650.0	1,650								
		Ampara						26	6.0	155	63	5.2	326	15	8.7	130	2	505.0	1,010								
		Trincomalee						8	13.1	105	16	9.7	155	3	6.4	19	2	51.5	103								
		Total						**51**	**7.2**	**366**	**89**	**6.2**	**550**	**18**	**8.3**	**149**	**5**	**552.6**	**2,763**								
	Central	Nuwa Eliya						8	32.3	259	4	8.2	33	1	16.2	16	0	#DIV/0!	0								
		Kandy						167	4.6	767	125	9.6	1,203	81	6.2	506	20	74.4	1,489								
		Matale						16	8.0	128	11	38.4	422	30	10.9	326	2	71.0	142								
		Kegalle						34	29.0	985	81	84.7	6,862	34	7.8	265	6	47.8	287								
		Total						**225**	**9.5**	**2,139**	**221**	**38.6**	**8,521**	**146**	**7.6**	**1,113**	**28**	**68.5**	**1,918**								
	WPN	**Gampaha**						**613**	6.5	**3,989**	**540**	4.8	**2,570**	**670**	4.6	**3,074**	**36**	190.4	**6,856**								
DD2 Total								**889**	**7.3**	**6,494**	**850**	**13.7**	**11,641**	**834**	**5.2**	**4,336**	**69**	**167.2**	**11,537**								
DD3	Sabaragamuwa	Rathnapura						46	7.3	337	99	9.3	918	119	5.7	673	28	87.0	2,437								
		Kegalle						5	3.8	19	55	3.3	181	23	5.9	136	7	59.5	417								
		Total						**51**	**7.0**	**356**	**154**	**7.1**	**1,099**	**142**	**5.7**	**809**	**35**	**81.5**	**2,854**								
	Uva	Badulla						18	7.9	142	58	8.2	476	28	4.9	138	3	166.3	499								
		Monaragala						5	14.4	72	51	8.3	423	11	13.0	144	6	93.1	558								
		Total						**23**	**9.3**	**214**	**109**	**8.2**	**899**	**39**	**7.2**	**282**	**9**	**117.5**	**1,057**								
	WPS II	Colombo						811	3.2	2,599	1,303	6.1	8,000	481	6.8	3,267	52	107.5	5,590								
		Kalutara						55	3.4	187	168	9.2	1,542	80	5.3	423	13	153.2	1,991								
		Total						**866**	**3.2**	**2,786**	**1,471**	**6.5**	**9,541**	**561**	**6.6**	**3,691**	**65**	**116.6**	**7,581**								
DD3 Total								**940**	**3.6**	**3,356**	**1,734**	**6.7**	**11,540**	**742**	**6.4**	**4,781**	**109**	**105.4**	**11,493**								
DD4	Southern	Galle						71	7.8	555	76	9.7	740	60	8.0	483	4	33.5	134								
		Matara						106	8.0	849	191	11.7	2,227	252	9.4	2,359	23	186.9	4,298								
		Hambantota						38	13.6	515	78	7.8	608	82	10.6	871	13	70.1	911								
		Total						**215**	**8.9**	**1,919**	**345**	**10.4**	**3,576**	**394**	**9.4**	**3,713**	**40**	**133.6**	**5,342**								
	WPS I	Colombo						732	4.6	3,342	614	8.0	4,926	311	5.7	1,761	14	222.2	3,110								
		Kalutara						30	4.2	127	49	8.2	402	37	5.6	206	6	121.5	729								
		Total						**762**	**4.6**	**3,469**	**663**	**8.0**	**5,328**	**348**	**5.7**	**1,967**	**20**	**192.0**	**3,839**								
DD4 Total								**977**	**5.5**	**5,388**	**1,008**	**8.8**	**8,903**	**742**	**7.7**	**5,681**	**60**	**153.0**	**9,182**								
CEB Total								**4,667**	**6.2**	**29,057**	**4,788**	**8.8**	**41,944**	**3,309**	**6.3**	**20,811**	**350**	**106.4**	**37,231**								

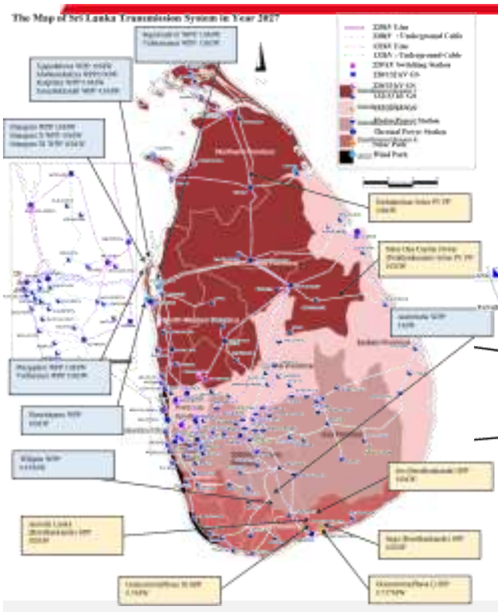
VRE Matter Information in MV Distribution Lines

After Soorya Bala Sangramaya									Major problems in 400 V supplied from each MV feeder																
Net Metering			Net Accounting			Net Plus			Forward	Reverse	Overload part	Voltage				Harmonic injection		Umbalance	Loss						
No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	max. (MW)	min. (MW)	[km, %,	max. (kV)	min. (kV)	Load factor	fluctuation (%,Hz)	degree n	rate (%)	(Phase,%)	(%)	Protection coordination	Short circuit current (A)	Islanding	Intermittency	Flexibility	Note
104	4.8	495	168	5.5	920	24	53	1,276																	
127	5.8	738	180	5.4	964	3	89	268																	
231	**5.3**	**1,233**	**348**	**5.4**	**1,884**	**27**	**57**	**1,544**																	
53	8.0	423	84	9.7	815	25	22	560																	
37	5.7	209	33	8.6	283	2	2	4																	
90	**7.0**	**632**	**117**	**9.4**	**1,098**	**27**	**21**	**563**																	
138	4.5	624	340	4.7	1,599	33	7	238																	
4	21.3	85	8	2.8	22	3	284	853																	
4	7.9	31	2	17.0	34	1	350	350																	
9	10.3	93	12	3.9	47	2	13	26																	
6	3.7	22	4	1.8	7	2	40	79																	
161	**5.3**	**855**	**366**	**4.7**	**1,709**	**41**	**38**	**1,546**																	
714	10.0	**7,139**	**160**	8.3	**1,321**	**17**	80.5	**1,368**																	
1,196	**8.2**	**9,860**	**991**	**6.1**	**6,013**	**112**	**44.8**	**5,020**																	
10	6.9	69	0	#DIV/0!	0	1	1,650.0	1,650																	
63	5.2	326	15	8.7	130	2	505.0	1,010																	
16	9.7	155	3	6.4	19	2	51.5	103																	
89	**6.2**	**550**	**18**	**8.3**	**149**	**5**	**552.6**	**2,763**																	
4	8.2	33	1	16.2	16	0	#DIV/0!	0																	
125	9.6	1,203	81	6.2	506	20	74.4	1,489																	
11	38.4	422	30	10.9	326	2	71.0	142																	
81	84.7	6,862	34	7.8	265	6	47.8	287																	
221	**38.6**	**8,521**	**146**	**7.6**	**1,113**	**28**	**68.5**	**1,918**																	
540	4.8	**2,570**	**670**	4.6	**3,074**	**36**	190.4	**6,856**																	
850	**13.7**	**11,641**	**834**	**5.2**	**4,336**	**69**	**167.2**	**11,537**																	
99	9.3	918	119	5.7	673	28	87.0	2,437																	
55	3.3	181	23	5.9	136	7	59.5	417																	
154	**7.1**	**1,099**	**142**	**5.7**	**809**	**35**	**81.5**	**2,854**																	
58	8.2	476	28	4.9	138	3	166.3	499																	
51	8.3	423	11	13.0	144	6	93.1	558																	
109	**8.2**	**899**	**39**	**7.2**	**282**	**9**	**117.5**	**1,057**																	
1,303	6.1	8,000	481	6.8	3,267	52	107.5	5,590																	
168	9.2	1,542	80	5.3	423	13	153.2	1,991																	
1,471	**6.5**	**9,541**	**561**	**6.6**	**3,691**	**65**	**116.6**	**7,581**																	
1,734	**6.7**	**11,540**	**742**	**6.4**	**4,781**	**109**	**105.4**	**11,493**																	
76	9.7	740	60	8.0	483	4	33.5	134																	
191	11.7	2,227	252	9.4	2,359	23	186.9	4,298																	
78	7.8	608	82	10.6	871	13	70.1	911																	
345	**10.4**	**3,576**	**394**	**9.4**	**3,713**	**40**	**133.6**	**5,342**																	
614	8.0	4,926	311	5.7	1,761	14	222.2	3,110																	
49	8.2	402	37	5.6	206	6	121.5	729																	
663	**8.0**	**5,328**	**348**	**5.7**	**1,967**	**20**	**192.0**	**3,839**																	
1,008	**8.8**	**8,903**	**742**	**7.7**	**5,681**	**60**	**153.0**	**9,182**																	
4,788	**8.8**	**41,944**	**3,309**	**6.3**	**20,811**	**350**	**106.4**	**37,231**																	

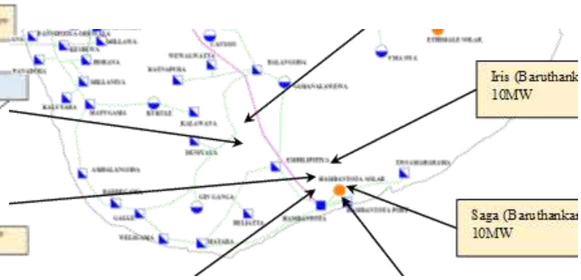
Which feeder is higher priority? What are the major matters?

VRE Information and Matters in Candidate Feeders

Large VRE Introduction in Power Grids



Draft LTGEP2020-2039(March 2020)
(p. E-13: Battery storage is proposed to be added to the system in phase development. Total 50 MW by 2025 and 100 MW by 2030 Exact capacities and entry years will be evaluated during the detailed design stage of battery storage integration.)



Storage battery system
20MW-10MWh @ Hambantota?

VRE Matter Collection per Substation/Feeder (Previous)

Division	Province	District	PSS Voltage (kV)	PSS	Feeder	High reliability (special customer, high-tech,	Total length (km)	Before Soorya Bala Sangramaya (2016-09-06)			After Soorya Bala Sangramaya																
								Net Metering			Net Metering			Net Accounting			Net Plus			Forward	Reverse	Overload part	Voltage				Harmonic
								No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	No of Consumers	Unit capacity (kW/capita)	Capacity (KW)	max. (MW)	min. (MW)	[km, %,	max. (kV)	min. (kV)	Load factor	fluctuation (%,Hz)	degree r
DD1	North Western	Kurunegala	33/11		01			111	4.3	482	104	4.8	495	168	5.5	920	24	53	1,276								
					02																						
					03																						
			132/33		01																						
					02																						
					03																						
		Puttalam						101	4.6	461	127																
		Total						**212**	**4.4**	**943**	**231**																
	North Central	Anuradhapura						41	9.7	396	53																
		Polonnaruwa						38	4.8	181	37																
		Total						**79**	**7.3**	**577**	**90**																
	Northern	Jaffna						146	4.1	596	138																
		Kilinochchi						9	17.4	157	4																
		Mullaitivu						2	6.9	14	4																
		Vavuniya						5	2.2	11	9																
		Mannar						6	3.3	20	6																
		Total						**168**	**4.7**	**798**	**161**																
	Colombo City	**Colombo**						**1,402**	8.2	**11,500**	**714**																
	DD1 Total							**1,861**	**7.4**	**13,819**	**1,196**																
DD2	Eastern	Batticaloa						17	6.2	106	10																
		Ampara						26	6.0	155	63																
		Trincomalee						8	13.1	105	16																
		Total						**51**	**7.2**	**366**	**89**																
	Central	Nuwa Eliya						8	32.3	259	4																
		Kandy						167	4.6	767	125																
		Matale						16	8.0	128	11																
		Kegalle						34	29.0	985	81																
		Total						**225**	**9.5**	**2,139**	**221**																
	WPN	**Gampaha**						**613**	6.5	**3,989**	**540**																
	DD2 Total							**889**	**7.3**	**6,494**	**850**																
DD3	Sabaragamuwa	Rathnapura						46	7.3	337	99																
		Kegalle						5	3.8	19	55																
		Total						**51**	**7.0**	**356**	**154**																
	Uva	Badulla						18	7.9	142	58																
		Monaragala						5	14.4	72	51																
		Total						**23**	**9.3**	**214**	**109**	**8.2**	**899**	**39**	**7.2**	**282**	**9**	**117.5**	**1,057**								
	WPS II	Colombo						811	3.2	2,599	1,303	6.1	8,000	481	6.8	3,267	52	107.5	5,590								
		Kalutara						55	3.4	187	168	9.2	1,542	80	5.3	423	13	153.2	1,991								
		Total						**866**	**3.2**	**2,786**	**1,471**	**6.5**	**9,541**	**561**	**6.6**	**3,691**	**65**	**116.6**	**7,581**								
	DD3 Total							**940**	**3.6**	**3,356**	**1,734**	**6.7**	**11,540**	**742**	**6.4**	**4,781**	**109**	**105.4**	**11,493**								
DD4	Southern	Galle						71	7.8	555	76	9.7	740	60	8.0	483	4	33.5	134								
		Matara						106	8.0	849	191	11.7	2,227	252	9.4	2,359	23	186.9	4,298								
		Hambantota						38	13.6	515	78	7.8	608	82	10.6	871	13	70.1	911								
		Total						**215**	**8.9**	**1,919**	**345**	**10.4**	**3,576**	**394**	**9.4**	**3,713**	**40**	**133.6**	**5,342**								
	WPS I	Colombo						732	4.6	3,342	614	8.0	4,926	311	5.7	1,761	14	222.2	3,110								
		Kalutara						30	4.2	127	49	8.2	402	37	5.6	206	6	121.5	729								
		Total						**762**	**4.6**	**3,469**	**663**	**8.0**	**5,328**	**348**	**5.7**	**1,967**	**20**	**192.0**	**3,839**								
	DD4 Total							**977**	**5.5**	**5,388**	**1,008**	**8.8**	**8,903**	**742**	**7.7**	**5,681**	**60**	**153.0**	**9,182**								
CEB Total								**4,667**	**6.2**	**29,057**	**4,788**	**8.8**	**41,944**	**3,309**	**6.3**	**20,811**	**350**	**106.4**	**37,231**								

Consideration of candidate feeders/substations by mass VRE data

>> VRE data were so many and were not managed sufficiently by feeder and substation.

What are the major matters?

>> Not severe matter up to now, and <u>insufficient measured output power/voltage data of use.</u>

>>> Selection of possible feeders as candidates

VRE Matter Collection at Substation (Revised)

DD LECO	Province	Area	Substation	2ndary kV	Feeder [Name]	Maximum active power flow				Maximum reactive power flow				Power factor		Max. current phase umbalance		
						Forward MW	Back ward MW	Forward MWh/day	Backward MWh/day	Forward MW	Backward MW	Forward MWh/day	Backward MWh/day	Max.	Min.	R %	Y %	B %
DD1	NCP	Minneriya	Valachchena New	33	F05													
DD1			Norochcholei Wind		F2													
DD1	NCP	Minneriya		33	Walikanda													
DD2			Sapugaskanda		F0													
DD2			Veyangoda		F8													
DD3	WPS2		Panadura		F1													
DD3			Pannipitiya		F4													
DD3			Horana		F4													
DD3			Horana		F6													
DD4			Hambantota	33	F2													
DD4			Hambantota	33	F4													
DD4	WPS1		Panadura	33	F07													
DD4	WPS1		Panadura	34	F08													

How were the candidate feeders selected?

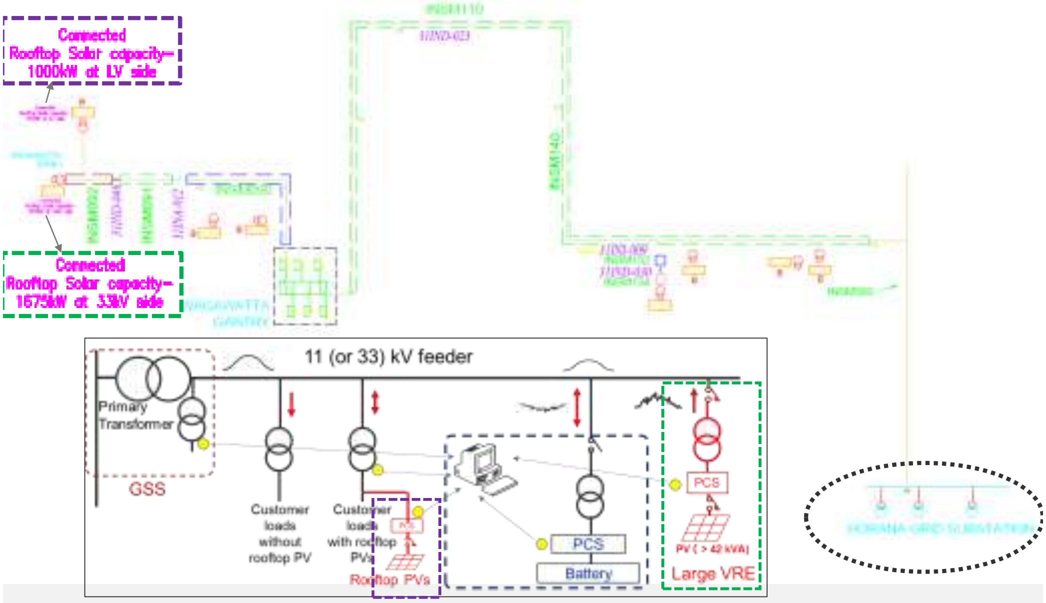
What are the major matters in the feeders?

Which feeders are higher priority?

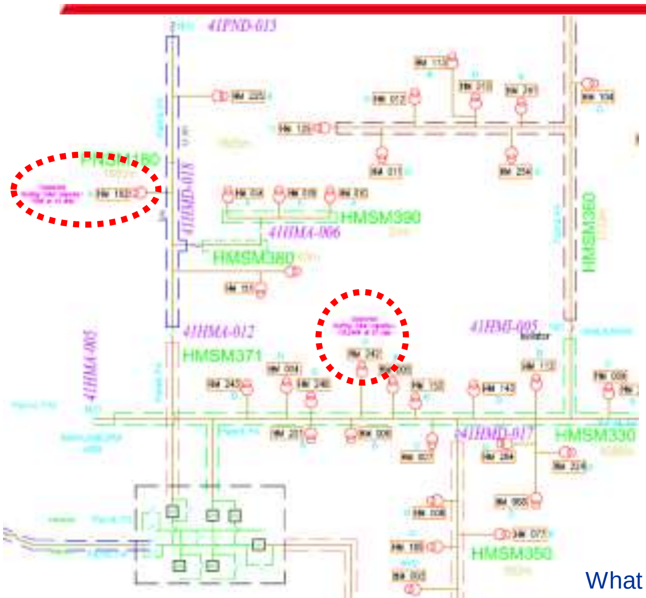
Feeder length km	Voltage Max. kV	Voltage Min. kV	Harmonic injection Max. %	Harmonic injection at degree n	Max. voltage phase umbalance R %	Y %	B %	Freqency Max. Hz	Freqency Min. Hz	Loss %	Protection coordination	Short circuit current (A)

>>> Any output power(current)/ voltage data?

VRE Connections in LV and MV Distribution Lines



VRE Matter Information in MV Distribution Lines



Location of problem in the candidate feeder		Problem	Voltage				
Source side	Load side		Max. (V)	Min. (V)	Unbalance (Phase, %)	Flicker (dV10 or Pst)	Instantaneous drop Drop (%)
(Rated Example)		(No problem)	253	207	10	0.45, 1	10
HM200	HM188	High voltage	260				
PN025		Low voltage		190			
HM275		Unbalance voltage in phase			12		
HM225		Flicker				1.1	
PN025		Instantaneous voltage drop					20
HM027		Harmonic injection					
Ditto		Harmonic injection					
None		Forward overload					
HM232	41HMD-024	Reverse overload					
HM040	HM121	Unbalance current in phase					
Ditto	Ditto	Unbalance current in phase					
41HMA-012	41PND-015	Short circuit current					
HM321	PN025	High loss					
Gantry	C.T.B. ABS	Protection coordination					
41HMD-049	41HMD-050	Islanding					
		Others					

What are the major matters?
Any output power(current)/ voltage data?

VRE Matter Collection in MV Feeder (Revised)

Location of problem in the candidate feeder		Problem	Voltage								Power (Current)							Coordination		Others
			Max.	Min.	Unbalance	Flicker	Instantaneous drop		Harmonic injection		Forward		Backward		Unbalance	Short circuit current	Loss	Protection	Islanding operation	
Source side	Load side		(V)	(V)	(Phase, %)	(dV10 or Pst)	Drop (%)	Duration (ms)	degree n	rate (%)	Max. (A)	Rated (A)	Min. (A)	Rated (A)	(Phase, %)	(kA)	(%)			Input other problem.
(Rated Example)		(No problem)	253	207	10	0.45, 1	10	10	Total	3	100%	100%	-100%	-100%	10	40	A few	Good	Never	
HM200	HM188	High voltage	260																	
PN025		Low voltage		190																
HM275		Unbalance voltage in phase			12															
HM225		Flicker				1.1														
PN025		Instantaneous voltage drop					20	100												
HM027		Harmonic injection							5	10										
Ditto		Harmonic injection							Total	3										
None		Forward overload									510	500								
HM232	41HMD-024	Reverse overload											-220	-200						
HM040	HM121	Unbalance current in phase													R_-10%					
Ditto	Ditto	Unbalance current in phase													Y_+10%					
41HMA-012	41PND-015	Short circuit current														45				
HM321	PN025	High loss															10			
Gantry	C.T.B. ABS	Protection coordination																NG		
41HMD-049	41HMD-050	Islanding																	NG	
		Others																		Outage by firing VRE, etc.

Where and When do the matters occur?
What are the matters in detail? Any output power(current)/ voltage data?

VRE Information in Each MV Feeder

400/230 V interconnection

Total PV power number: 2
Total PV power capacity: 175 kVA

Input PV power capacity such as rooftop per transformer

Transformer ID,etc.	Subtotal capacity	
HM259	100	kVA
HM192	75	kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA

Total Wind power number:
Total Wind power capacity:

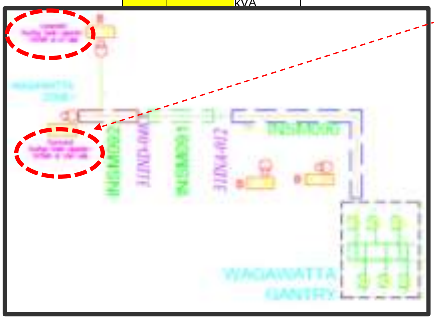
Input Wind power capacity per transformer

Transformer ID,etc.	Subtotal capacity	
		kVA
		kVA

11 kV interconnection

Total PV power number:
Total PV power capacity: kVA

Transformer ID,etc.	Capacity	
		kVA



Transformer ID,etc.	Capacity	
		kVA
		kVA

33 kV interconnection

Total PV power number: 1
Total PV power capacity: 1,675 kVA

Transformer ID,etc.	Capacity	
IN501	1,675	kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA
		kVA

Total Wind power number:
Total Wind power capacity:

Transformer ID,etc.	Capacity	
		kVA
		kVA

Data collection sheet of installed VRE per distribution transformer
Easy to consider where and how much of power flow

Confirmation of Problems

in the Candidate Feeders

Possibility of Problems by VRE in the Candidate Feeders

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Any obvious problems up to now?

DD / LECO	Province	Area	Substation	2nd ary kV	Feeder [Name]	Active power flow Forward MW	Active power flow Backward MW	Reactive power flow Forward MW	Reactive power flow Backward MW	Power factor	Current umbalance R %	Current umbalance Y %	Current umbalance B %	Voltage Max. kV	Voltage Min. kV	Voltage umbalance R %	Voltage umbalance Y %	Voltage umbalance B %	Harmonic injection Max. %	Harmonic injection at degree n %	Freqency Hz	Loss %	Protection coordination	Short circuit current (A)
DD1	NCP	Minneriya	Valachchena New	33	F05	No obvious problem	Problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	?	?	Norochcholei Wind	33	F2	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	NCP	Minneriya	?	33	Walikanda	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD2	?	?	Sapugaskanda	33	F0	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	?	?	Veyangoda	33	F8	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD3	WPS2	?	Panadura	33	F1	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	?	?	Pannipitiya	33	F4	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	?	?	Horana	33	F4	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	?	?	Horana	33	F6	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
DD4	SP	?	Hambantota	33	F2	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	SP	?	Hambantota	33	F4	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	WPS1	?	Panadura	33	F07	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem
	WPS1	?	Panadura	33	F08	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem	No obvious problem

Questionnaires to DDs and LECO

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NIPPON KOEI

	DD1	DD2	DD3	DD4	LECO
Candidate feeders	3	2	4	4	?
Power/Voltage data at S/S					
Severe VRE matters					
Voltage control as project estimation					
Geographical Information system (GIS) drawings like MV line route on graphic map or aerial photomap					
Electric constant data such as R, X, %Z in the candidate feeders					
Role division in preparation of storage battery system					
Measurement at S/S, T/F, PV site, SBS					
Communication way for data transfer					

Candidate Feeders

Target feeder information to measure and analyze

Input the target feeder information to measure and record data.

Organization	DD1, 2, 3, 4, LECO
Province	
Area (District)	
Substation name	
Feeder No.	

Please answer yes or no about the availability of data transmission (communication) network way at the target area.

Class	2G	2.5G	3G	4G	5G	Other way such as optical fiber, CEB own line, OPGW, etc.
Target area						
Substation						
VRE installation						
Feeder end						
Other areas						

Please answer yes or no, according to whether you can presently measure and record the following data at the following points.

Effective value (Root mean square)

Measurement area	Measurement point	Freqency	Power factor	Voltage at each phase			Current at each phase			Apparent power						Active power						Active power					
				R	Y	B	R	Y	B	Forward			Backward			Forward			Backward			Forward			Backward		
										R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B
		Hz		V	V	V	A	A	A	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA
Substation	at the CT and VT terminal in the panel																										
Substation	?																										
VRE installation	secondary side (230V) of the PCS																										
VRE installation	?																										
Feeder end	secondary side (230V) of the 33/0.4kV T/F																										
Feeder end																											
others	?																										
?	?																										
?	?																										

Instantaneous value (wave form)

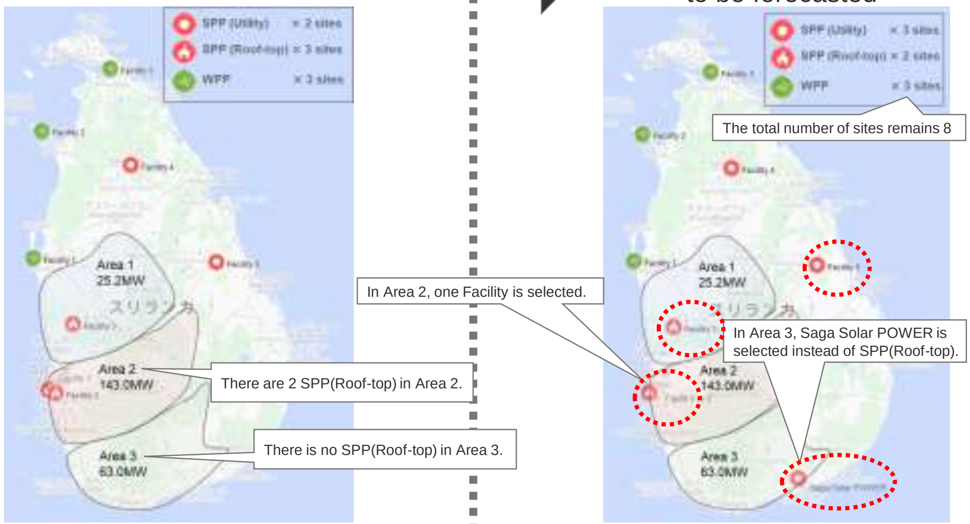
Measurement area	Measurement point	Freqency	Power factor	Voltage at each phase			Current at each phase			Apparent power						Active power						Active power						Harmonic injection at degree n
				R	Y	B	R	Y	B	Forward			Backward			Forward			Backward			Forward			Backward			
										R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	
		Hz		V	V	V	A	A	A	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	%
Substation	at the CT and VT terminal in the panel																											
Substation	?																											
VRE installation	secondary side (230V) of the PCS																											
VRE installation	?																											
Feeder end	secondary side (230V) of the 33/0.4kV T/F																											
Feeder end																												
others	?																											
?	?																											
?	?																											

Sharing of VRE Forecasting Site Information in WG 2 for Measurement and Analysis in WG 3-2

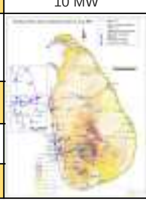
WG2 Location of Facility for VRE forecast in WG2

received Facility Location

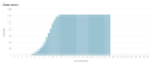
Selected sites to be forecasted



WG2 Facility Information of VRE forecasted (SPP)

	Utility PV			Roof-top PV (Decide either Facility 1 or Facility 2)		
	SPP1	SPP2	SPP3	SPP4	SPP5	SPP5
Facility No.	Facility 4	Facility 5	Saga Solar POWER	Facility 3	Facility 1	Facility 2
Information/Site	10 MW Solar Power plant (Vydexa solar power plant)	Solar One Ceylon Power (Pudukadumalai) SPP	SAGA SOLAR POWER		Rooftop PV Colombo	Rooftop PV Sri Jayawardanapura
Area	Vavuniyava	Welikanda	Hambantota	Kuliyapitiya	Slave Island	Battaramulla
Premises	Privately Owned	Privately Owned			**CEB Head office**	CEB DD3 Office
Location (Lat/lon)	8°46'9.49"N, 80°31'39.88"E	7°58'31.38"N 81°14'18.23"E	6.22 , 81.085	7.469655377230161, 80.05004525435352	6.930312772873491, 79.84709213773222	6.902537738866525, 79.90319016628004
Period of Installation	Jul-17	Dec-16	2015-2016	09/02/2018	installed 2019-jun-25	installed 2017-jan-11
Panel Azimuth Angle			0	90°	30 degree	12 degree
Panel Tilt Angle	Single-Axis Tracking	Single-Axis Tracking	5 degrees to 15	35°	8 degree	10 degree
Type of Installation	Gound Mounted	Gound Mounted	GMFT	roof	on small structure	on roof
Type of PV Module	350p Monocrystalline	315Wp & 320Wp Polycrystalline	MULTI CRYSTALINE	Monocrystalline	MONO PERC	Mono
Total Panel Capacity	10 MW	12.5 MW	255, 260, 265Wp	179	90.885kWp	50kWp
PCS or Inverter model			ABB	SMA Gmbh STP 25000 TL-30	TR10-20.0-TL-OUTD-S2X-400 X 1 no /TR10-27-6-TL-OUTD-400 X 3 No	SMA 25TL
PCS or Inverter Capacity			1MW*10	25kVA	20kW X 1 No and 27kW X 3 No	2 of SMA 25TL
Online Data Availability (If possible)				Yes	Yes	No
Past Data availability (If possible)				Yes	Yes	Yes

WG2 Facility Information of VRE forecasted (WPP)

	WPP1	WPP2	WPP3
Facility No.	Facility 3	Facility 2	Facility 1
Information	Northern Wind power plant	Mannar Wind power plant	Wind plant from cluster in Puttalam
Site	Vallimunai 10MW Wind Power plant	Thambapavani Wind Power plant (CEB)	Mampuri Wind Power Plant– Stage I
Area	Jaffna	Mannar Island	Puttalam
Premises	Beta Power (Pvt) Ltd	Thambapavani Wind Power plant	Mampuri Wind Power Plant
Location (Lat/lon)	9.556760792037888, 80.35954521288103	9.050124, 79.792038	8°0'36.37"N, 79°43'24.09"E
Period of Installation	December 2014	End 2020- Being Commissioned	2010
Number of wind turbines	8	30	8
Wind turbine rated capacity per unit	1,500 kW (ReGen VENSYS 82V82)	3,450kW	1,250kW
Total amount of wind turbine capacity	10 MW or 40MW?	100 MW	10 MW
Wind turbine hub height	85m	80 m	60m
Power curve (includes cut-in, rated, cut-out wind speed)	Cut-in wind speed: 2.5 m/s Rated wind speed: 13 m/s Cut-off wind speed: 22.5 m/s http://www.regenpowertech.com/104/wind-turbine	Rated power: 3,450 kW Cut-in wind speed: 3 m/s Cut-out wind speed: 22.5 m/s Re cut-in wind speed: 20 m/s Wind class IEC IIIA/IEC IIB https://www.vestas.com/en/products/4-mw-platform/v136-_3_45_mw#!technical-specifications	 Power Curve Data- https://www.thewindpower.net/turbine_en_220_suzlon_s64-1250.php
Past Data availability (If possible)			

Important items for Building VRE forecast model

Request more information

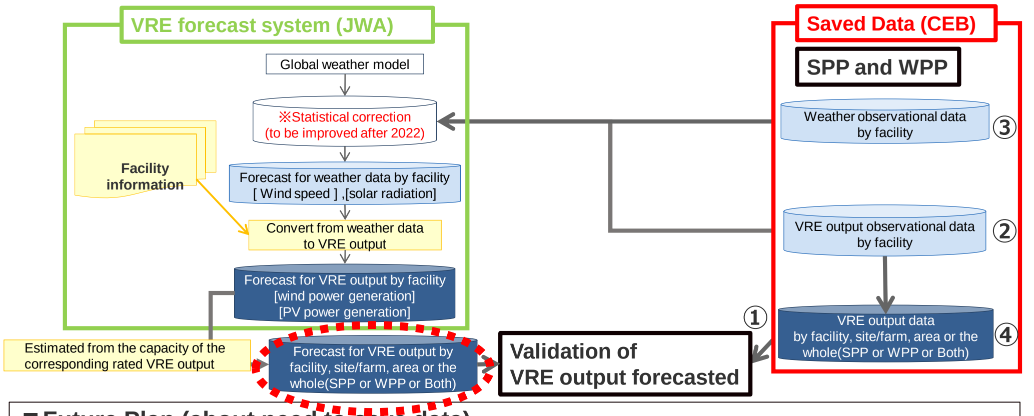
WG2 Confirmation of Past Data availability

	SPP					WPP		
	Utility PV			Roof-top PV				
	SPP1	SPP2	SPP3	SPP4	SPP 5 ~~or 6~~	WPP 1	WPP 2	WPP 3
Facility information (mainly location)	○	Valachchenai F5?	Hanbantota	Kuliyapitiya	Head office ~~or DD3 office~~	○	○	○
Supply responsibility		DD1, DD2	DD4	DD1?	DD1?			
Weather observation data (Past Data availability)								
VRE output data (Past Data availability)			Yes (Partially)	Yes	Yes			

Please collect the data!

■ Future Plan
・In the next Field Work,
WG2 will discuss "Approach to forecast Area VRE output" and "How to save the VRE output and weather (if any) data for validation of VRE output forecasted (ex: by facility, site/farm, area or the whole(SPP or WPP or Both))".

WG2 Validation of VRE output forecasted (Future Plan)



■Future Plan (about need to save data)

① **The whole VRE output data (SPP and WPP)** is mandatory **for the validation**.

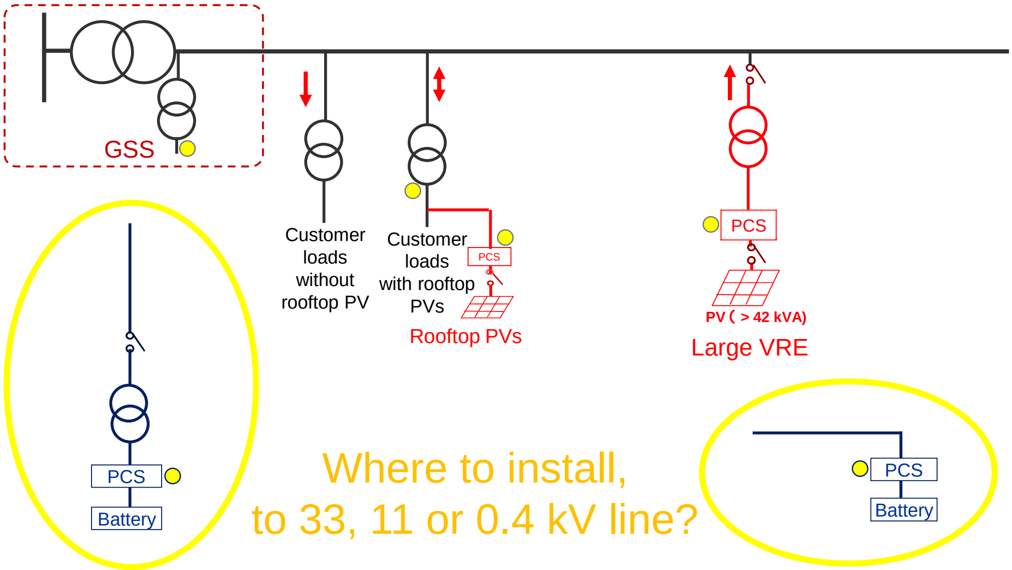
② By facility, to save VRE output data is also mandatory.

③ To save the weather observational data (or nearest meteorological station data) by facility is better for stational correction for the future.

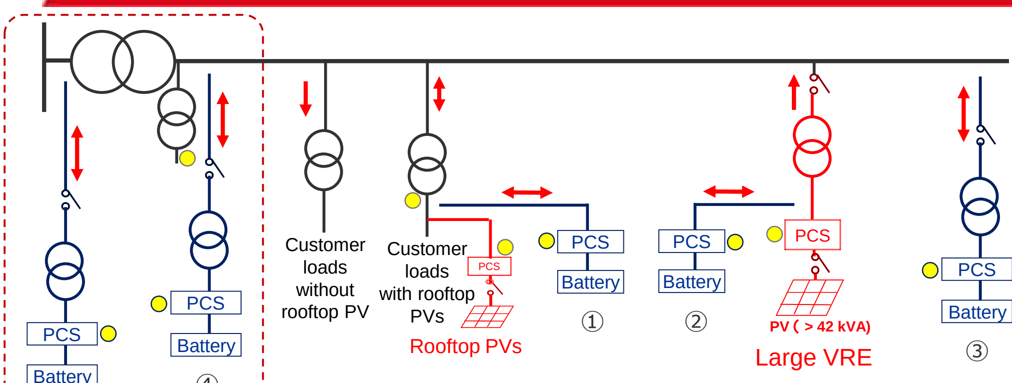
④ If possible, it is desirable to save VRE output data by site/farm and by area.

Candidate Feeder for BESS Pilot Project

Where to Install Storage Battery System

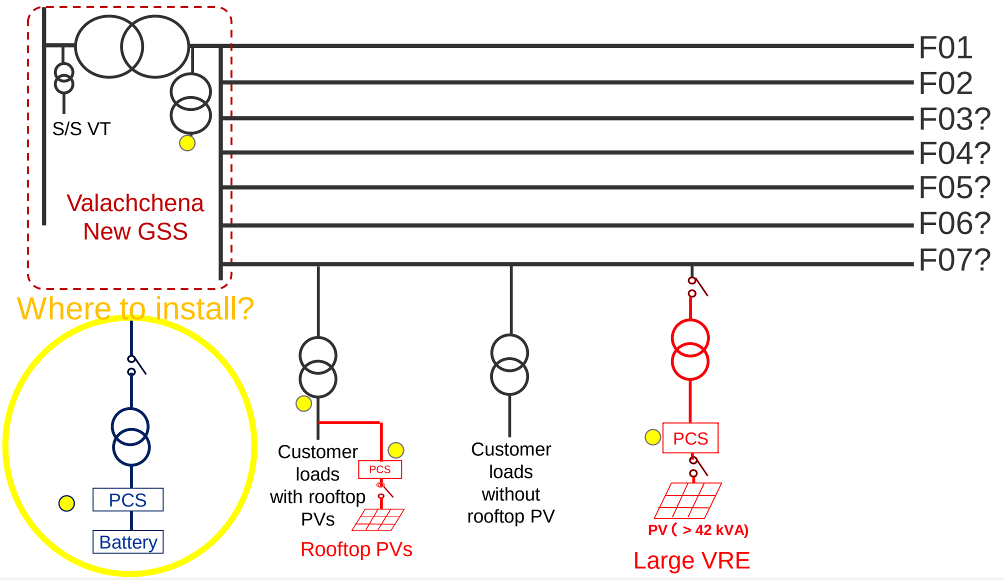


Where to Install Storage Battery System



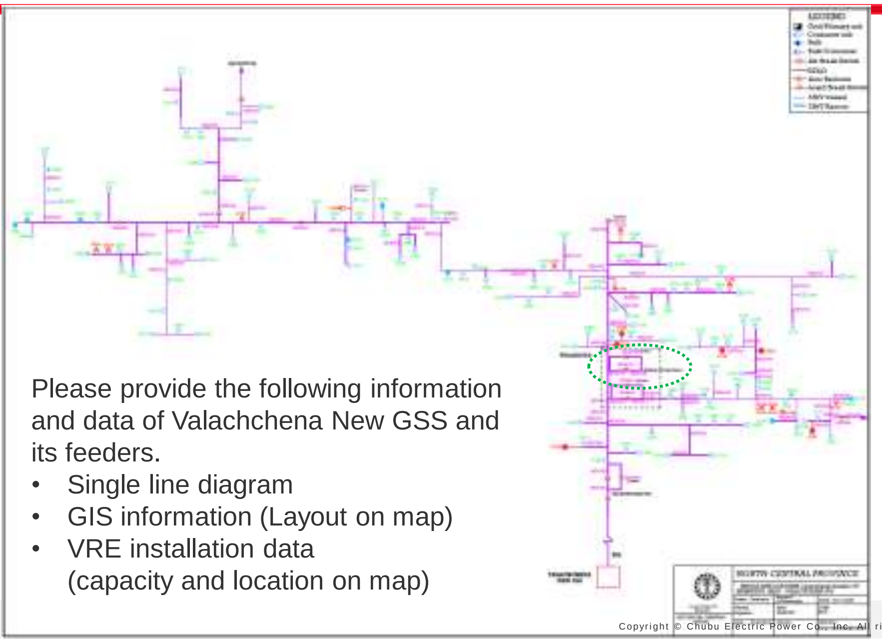
No.	Capacity	Cost	Main matters	Effect	Possibility
①	Small	Low	Voltage, Power flow?	Middle?	Middle?
②	Small	Low	Power flow?	High?	?
③	Middle	Middle	Voltage?	Middle?	Low?
④	Large	High	Power flow?	Low?	Very low?

Case of SBS installation to Valachchena New GSS



Output Power/Voltage Data Measurement

Target MV System for the Pilot Project

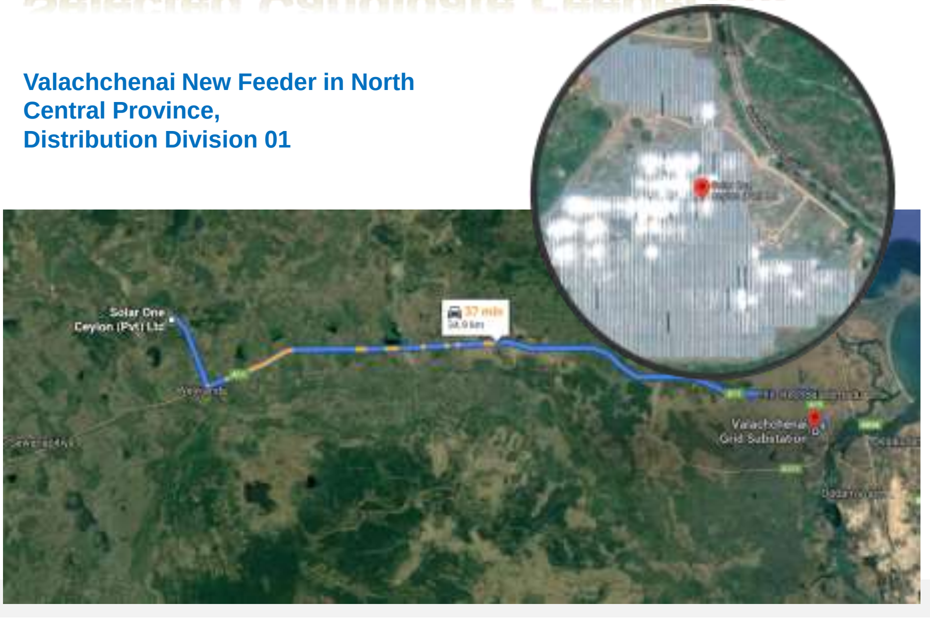


Please provide the following information and data of Valachchena New GSS and its feeders.

- Single line diagram
- GIS information (Layout on map)
- VRE installation data
  (capacity and location on map)

Selected Candidate Feeder….

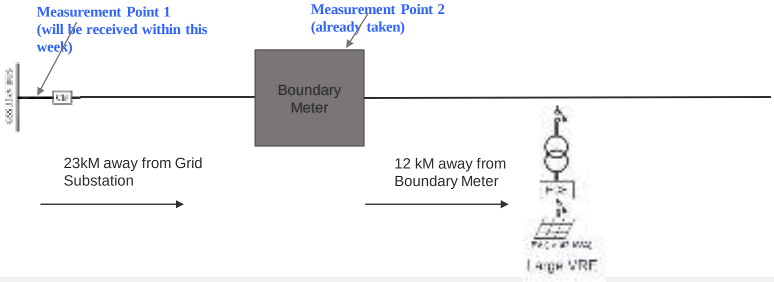
Valachchenai New Feeder in North Central Province, Distribution Division 01



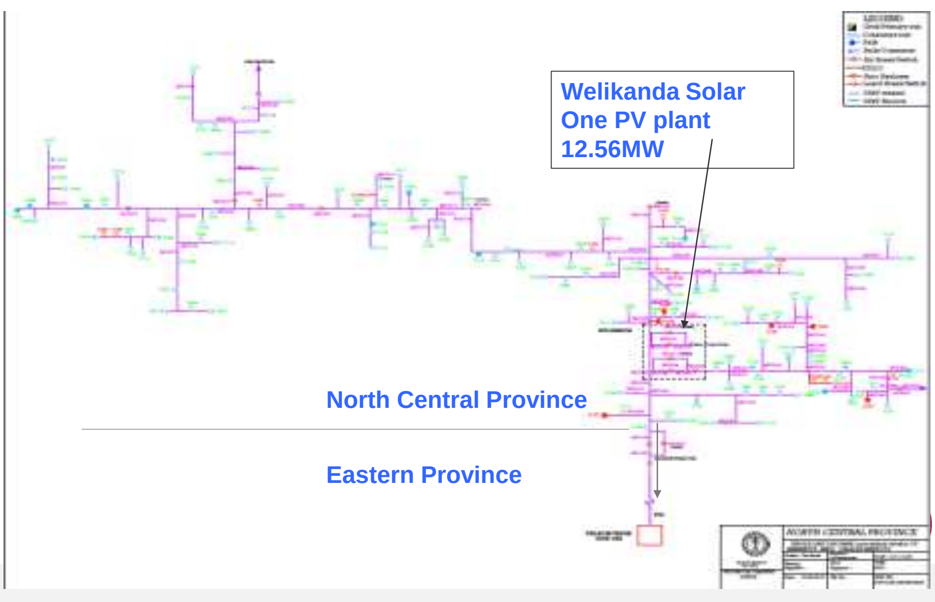
Selected Candidate Feeder….

This feeder selected due to

- a 12.56 MWp Solar PV plant connected with a single axis tracker at Welikanda 35 Km away from the Grid Substation and 12kM away from the boundary meter (Kadawathmaduwa)
- Boundary meter data obtained and have requested Grid Substation meter data
- In daytime most of the time have reverse power flow.

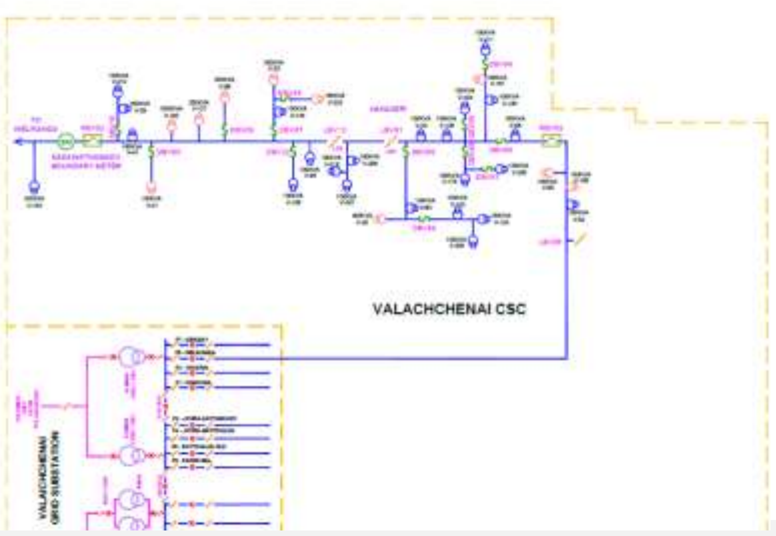


Selected Candidate Feeder….



Selected Candidate Feeder…..

Eastern Province



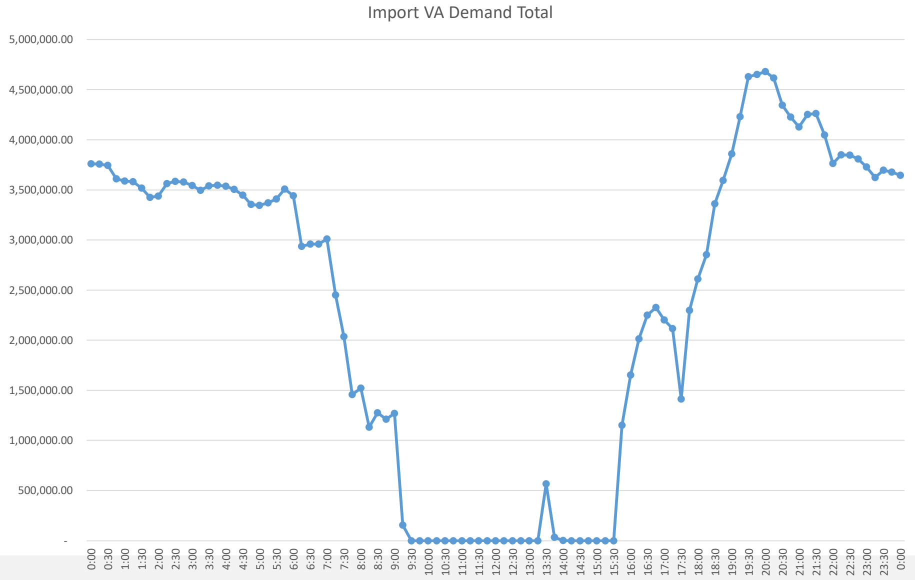
Measured data at Boundary Meter…..

Record No	Date/Time		Import VA Demand Total	Import W Demand Total	Avg Power Factor Total	Export VA Demand Total	Export W Demand Total	Demand Avg var Total	Record Status
418413	1/8/2020 0:00		3,761,000.00	3,713,000.00	0.9871	-	-	572,900.00	W...
418414	1/8/2020 0:15		3,758,000.00	3,711,000.00	0.9875	-	-	562,000.00	W...
418415	1/8/2020 0:30		3,744,000.00	3,698,000.00	0.9870	-	-	557,200.00	W...
418416	1/8/2020 0:45		3,615,000.00	3,566,000.00	0.9873	-	-	547,600.00	W...
418417	1/8/2020 1:00		3,588,000.00	3,540,000.00	0.9866	-	-	561,100.00	W...
418418	1/8/2020 1:15		3,585,000.00	3,534,000.00	0.9865	-	-	560,500.00	W...
418419	1/8/2020 1:30		3,518,000.00	3,475,000.00	0.9878	-	-	533,000.00	W...
418420	1/8/2020 1:45		3,425,000.00	3,381,000.00	0.9875	-	-	498,700.00	W...
418421	1/8/2020 2:00		3,437,000.00	3,400,000.00	0.9890	-	-	457,400.00	W...
418422	1/8/2020 2:15		3,565,000.00	3,512,000.00	0.9887	-	-	482,500.00	W...
418423	1/8/2020 2:30		3,584,000.00	3,544,000.00	0.9880	-	-	487,800.00	W...
418424	1/8/2020 2:45		3,580,000.00	3,541,000.00	0.9882	-	-	482,500.00	W...
418425	1/8/2020 3:00		3,545,000.00	3,506,000.00	0.9890	-	-	482,600.00	W...
418426	1/8/2020 3:15		3,487,000.00	3,457,000.00	0.9889	-	-	488,900.00	W...
418427	1/8/2020 3:30		3,509,000.00	3,498,000.00	0.9886	-	-	492,100.00	W...
418428	1/8/2020 3:45		3,547,000.00	3,509,000.00	0.9892	-	-	474,600.00	W...

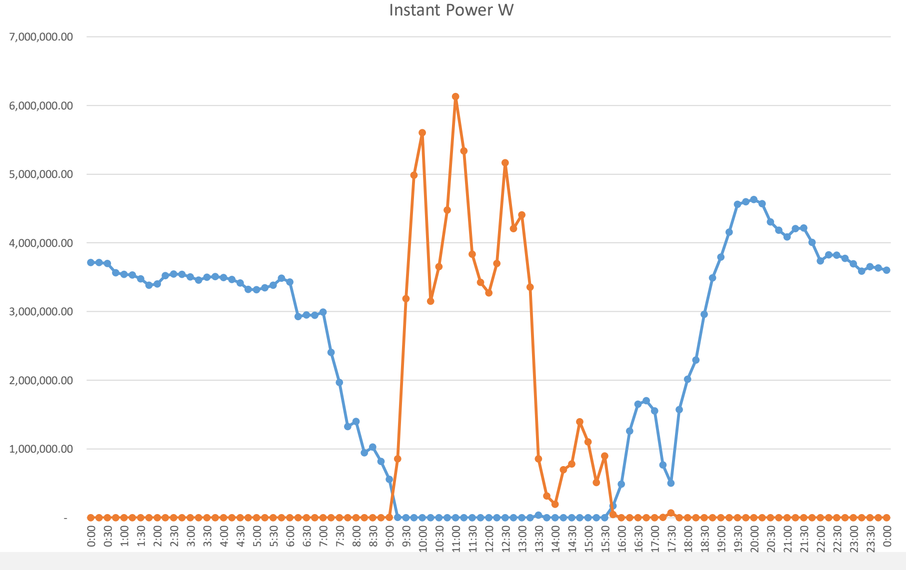
- **15 min Interval Data obtained**
- **Import and export VA Recorded**
- **Average Power Factor Recorded**
- **Import and Export W recorded**

- **Other data not available at the moment**

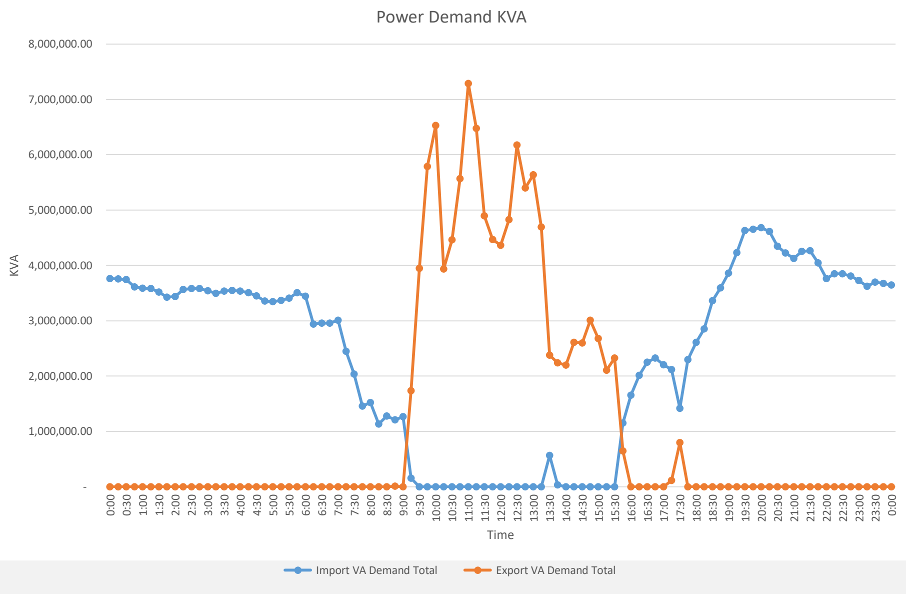
Measured data at Boundary Meter…..



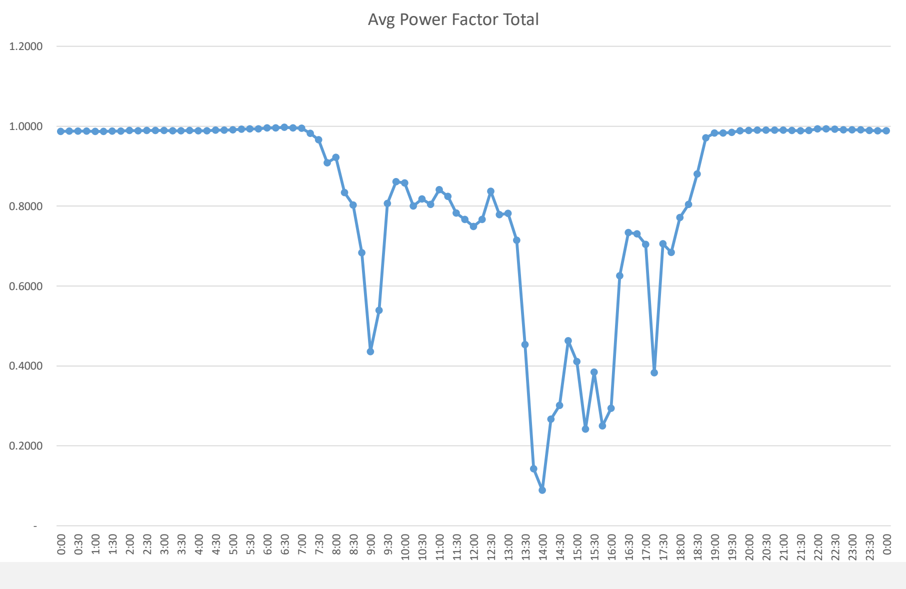
Measured data at Boundary Meter…..



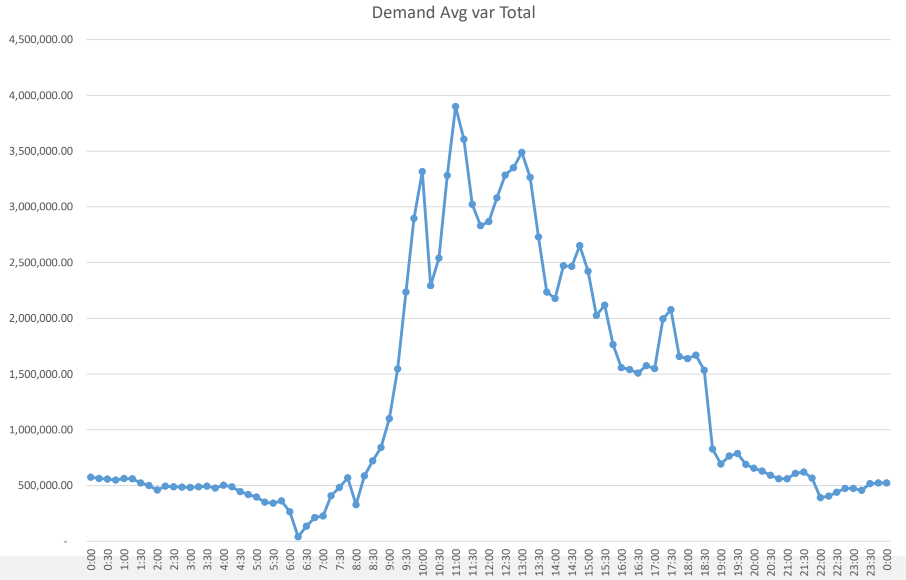
Measured data at Boundary Meter…..



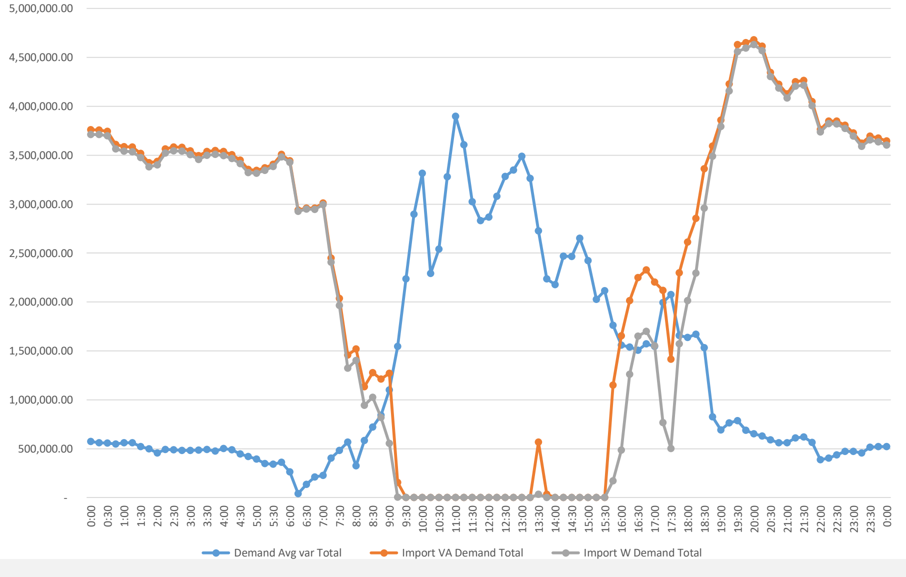
Measured data at Boundary Meter…..



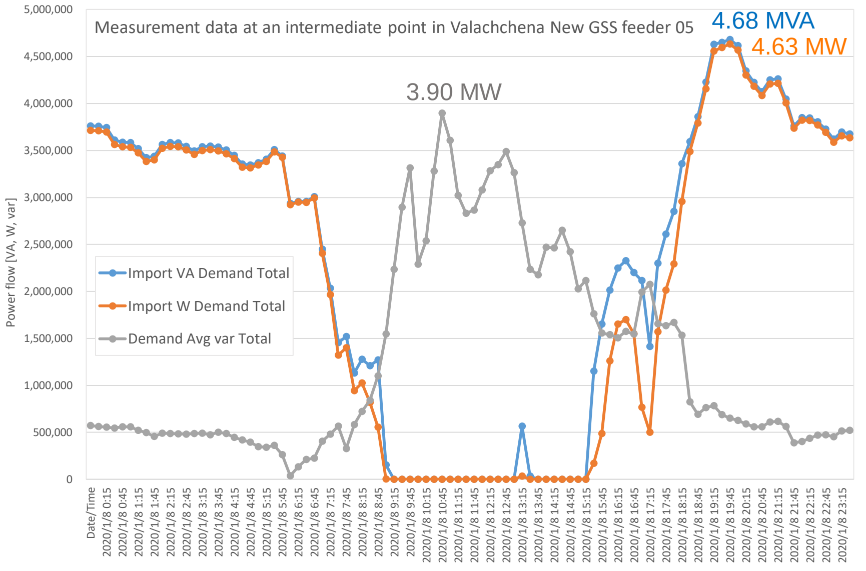
Measured data at Boundary Meter…..



Measured data at Boundary Meter…..



Recorded Power Flow in the Target Valachchena F05



Measured Data at the target substation and feeder for 24 hours

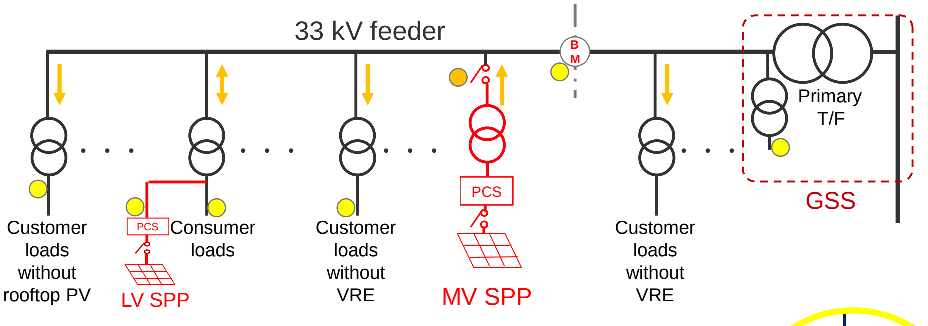
	Transformer 01					33kV Feeder 5
Time	kV	A	PF	MW	MVAR	A
0.30	33.5	146	0.99	8.2	0.5	71
1.00	33.6	142	0.99	8.00	0.5	68
1.30	33.6	139	1.00	7.8	0.4	70
2.00	33.3	136	1.00	7.6	0.3	70
2.30	33.3	136	1.00	7.6	0.3	70
3.00	33.3	136	1.00	7.6	0.3	70
3.30	33.3	136	1.00	7.6	0.7	70
4.00	33.3	136	1.00	7.6	0.7	70
4.30	33.1	138	1.00	7.2	0.3	70
5.00	33.1	141	1.00	7.8	0.3	69
5.30	32.6	151	1.00	8.2	0.2	72
6.00	32.5	142	0.99	7.8	0.4	59
6.30	32.8	114	0.99	6.2	0.2	35
7.00	32.8	114	0.99	6.2	0.7	35
7.30	32.7	108	0.98	5.8	0.9	27
8.00	33	112	0.97	6.00	1.2	32
8.30	33	107	0.96	5.8	1.5	29
9.00	32.7	73	0.74	5.1	2.5	(-)90
9.30	32.8	79	0.73	3.2	2.9	(-)117
10.00	32.8	85	0.76	3.6	2.9	(-)92
10.30	33	88	0.66	3.2	3.5	(-)127
11.00	33	96	0.8	4.2	3	(-)97
11.30	33.2	108	0.88	5.3	2.7	(-)60
12.00	33.1	89	0.74	3.6	3.2	(-)127
12.30	33.2	99	0.79	4.6	3.2	(-)70
13.00	33.4	115	0.93	6.00	2.2	(+)38
13.30	33.5	113	0.91	5.8	2.4	(-)42
14.00	33.5	106	0.9	5.3	2.6	(-)48
14.30	33.4	115	0.93	6.00	2.2	35
15.00	33.4	118	0.94	6.2	2.1	33
15.30	33.2	124	0.95	6.6	2.00	35
16.00	33.2	134	0.95	7.1	2.1	48
16.30	33.4	131	0.95	7.1	2.1	47
17.00	33.3	126	0.95	6.8	2.00	40
17.30	33.5	130	0.96	7.00	2.00	51
18.00	33.7	141	0.97	7.8	1.7	64
18.30	33.5	161	0.99	9.1	1.00	78
19.00	33.7	192	0.99	10.7	2.5	91
19.30	32.6	197	1.00	10.8	0.3	93
20.00	33.00	190	1.00	10.6	0.2	86
20.30	33.4	187	1.00	10.5	0.4	85
21.00	33.6	183	1.00	10.3	0.4	83
21.30	33.4	174	1.00	9.8	0.4	79
22.00	33.7	170	1.00	9.6	0.5	76
22.30	32.8	161	1.00	8.9	0.4	74
23.00	32.9	158	0.99	8.7	0.4	75
23.30	33.00	152	0.99	8.7	0.5	72
24.00	33.3	148	0.99	8.3	0.6	69

Modeling of Target Feeder

to Measure and Analyze Output Power/Voltage

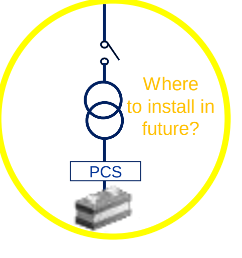
- Valachchenai F5 -

Evaluation of Valachchenai F5 - DD1 and DD2 Area -

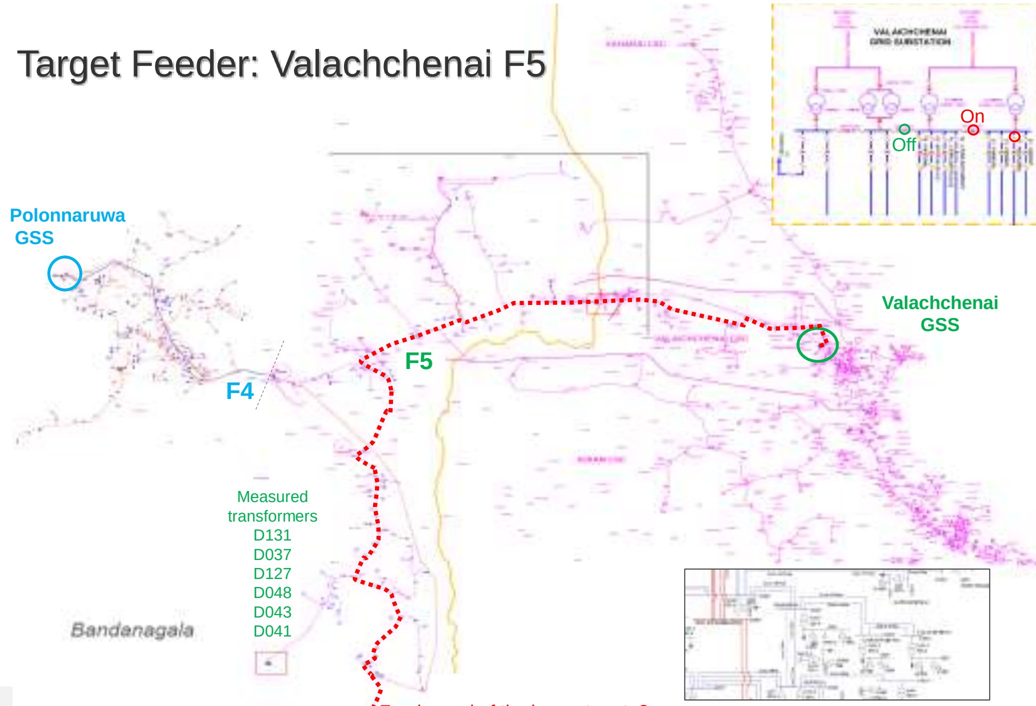


Evaluation steps of Valachchenai F5

1. Modeling load, VRE and facility information (line constant, load/VRE dispersion)
2. Calculating output power/voltage
3. Measuring at several effective points
4. Estimating present power/voltage fluctuation



Target Feeder: Valachchenai F5



Modeling of Valachchena F5

Modeling of distributed load and VRE and facility information (line constant, etc.)

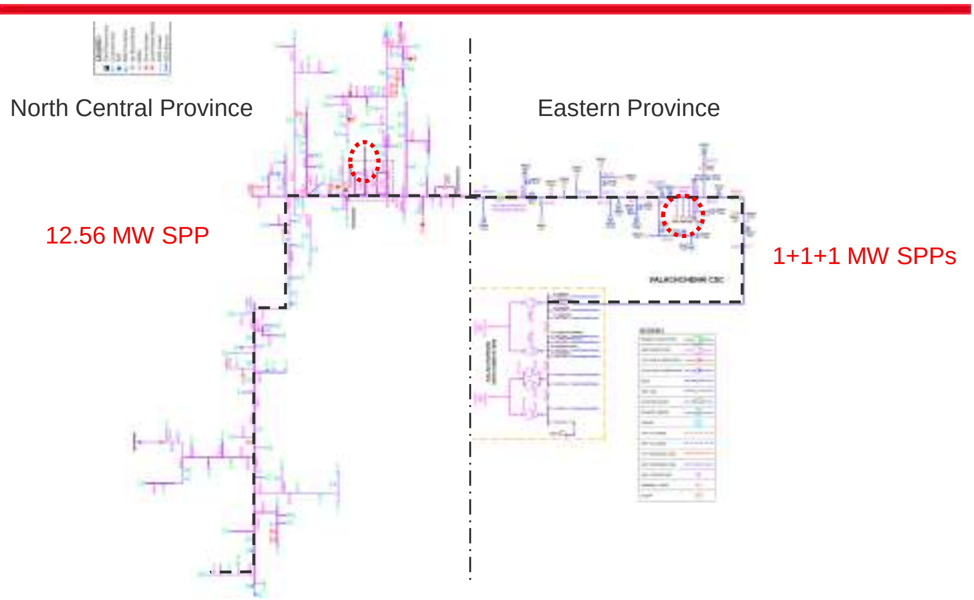
Valachchenai F5 — Load ratio 50% — G ratio 80%

Main route			Load			Generator		Remarks	Line specifications			
S/S side	MV line end side	Length	Tr (Load) capacity	Total Tr (load) capacity	Load ratio [(SS load) /(Total Tr capacity)]	VRE capacity	Generation capacity	Particular generator or load to care such as synchronous or induction generator/motor, self- or separately- excited inverter	Wire type	Wire size	Resistance, R	Reactance, X
(Grid power source side)	(Connection point)	m	kVA	kVA	kVA	kVA	kVA	–	–	mm^2	ohm/km	ohm/km
GSS	V82		160	5,280	2,640		0					
V82	V166		160	5,120	2,560		0					
V166	V98B		100	4,960	2,480		0					
V98B	RBV05			4,860	2,430		0					
RBV05	V56		160	4,860	2,430		0					
V56	DBV05			4,700	2,350		0					
DBV05	V126+V161+V211		300	4,700	2,350		0					
V126+V161+V211	V194+V179+V208		300	4,400	2,200		0					
V194+V179+V208	Proposed 3MW PV			4,100	2,050	3,000	2400	Interconnection in 33 kV line				
Proposed 3MW PV	V135		100	4,100	2,050		0					
V135	V34		100	4,000	2,000		0					
V34	V60+V25+V102+V103+V200		860	3,900	1,950		0					
V60+V25+V102+V103+V200	LBV01			3,040	1,520		0					
LBV01	V206+V216+V207		300	3,040	1,520		0					
V206+V216+V207	LBV13			2,740	1,370		0					
LBV13	V36		100	2,740	1,370		0					
V36	V156		100	2,640	1,320		0					
V156	V134+V33+V223		420	2,540	1,270		0					
V134+V33+V223	V89		250	2,120	1,060		0					
V89	V127		250	1,870	935		0					
V127	V182		1,000	1,620	810		0					
V182	V31		100	620	310		0					
V31	V47		160	520	260		0					
V47	V29+V212		260	360	180		0					
V29+V212	RBV02			100	50		0					
RBV02	BM			100	50		0					
BM	V183 (=D165?)		100	100	50		0		Racoon(ACSR?)	?	?	???
V183 (=D165?)	D074+D091			0	0		0		Racoon(ACSR?)	?	?	???
D074+D091	D119+D187			0	0		0		Racoon(ACSR?)	?	?	???
D119+D187				0	0		0		Racoon(ACSR?)	?	?	???
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0		Weasel(ACSR)	?	?	???

- DD2 Area -

- DD1 Area -

Valachchenai F5 with 12.56 MW SPP - DD1 and DD2 Area -



Modeling of Valachchena F5

Modeling of distributed load and VRE and facility information (line constant, etc.)

Valachchenai F5 — Load ratio 50% — G ratio 80%

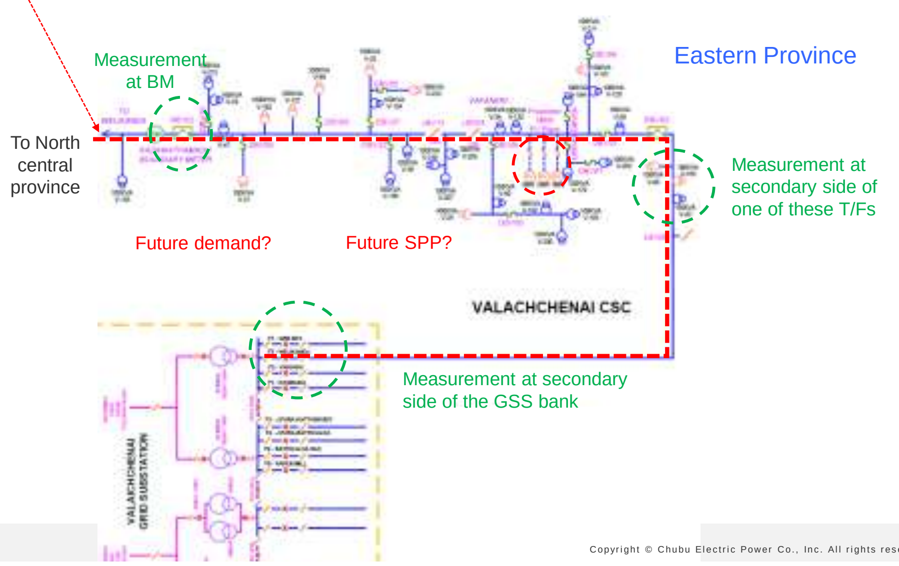
Main route			Load			Generator		Remarks	Line specifications			
S/S side	MV line end side	Length	Tr (Load) capacity	Total Tr (load) capacity	Load ratio [(SS load)/(Total Tr capacity)]	VRE capacity	Generation capacity	Particular generator or load to care such as synchronous or induction generator/motor, self- or separately- excited inverter	Wire type	Wire size	Resistance, R	Reactance, X
(Grid power source side)	(Connection point)	m	kVA	kVA	kVA	kVA	kVA	–	–	mm^2	ohm/km	ohm/km
GSS	V82		160	5,280	2,640		0					
V82	V166		160	5,120	2,560		0					
V166	V98B		100	4,960	2,480		0					
V98B	RBV05			4,860	2,430		0					
RBV05	V56		160	4,860	2,430		0					
V56	DBV05			4,700	2,350		0					
DBV05	V126+V161+V211		300	4,700	2,350		0					
V126+V161+V211	V194+V179+V208		300	4,400	2,200		0					
V194+V179+V208	Proposed 3MW PV			4,100	2,050	3,000	2400	Interconnection in 33 kV line				
Proposed 3MW PV	V135		100	4,100	2,050		0					
V135	V34		100	4,000	2,000		0					
V34	V60+V25+V102+V103+V200		860	3,900	1,950							
V60+V25+V102+V103+V200	LBV01			3,040	1,520							
LBV01	V206+V216+V207		300	3,040	1,520							
V206+V216+V207	LBV13			2,740	1,370							
LBV13	V36		100	2,740	1,370		0					
V36	V156		100	2,640	1,320		0					
V156	V134+V33+V223		420	2,540	1,270		0					
V134+V33+V223	V89		250	2,120	1,060		0					
V89	V127		250	1,870	935		0					
V127	V182		1,000	1,620	810		0					
V182	V31		100	620	310		0					
V31	V47		160	520	260		0					
V47	V29+V212		260	360	180		0					
V29+V212	RBV02			100	50		0					
RBV02	BM			100	50		0					
BM	V183 (=D165?)		100	100	50		0		Racoon(ACSR?)	?	?	???
V183 (=D165?)	D074+D091			0	0		0		Racoon(ACSR?)	?	?	???
D074+D091	D119+D187			0	0		0		Racoon(ACSR?)	?	?	???
D119+D187				0	0		0		Racoon(ACSR?)	?	?	???
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0					
0				0	0		0		Weasel(ACSR)	?	?	???

- DD2 Area -

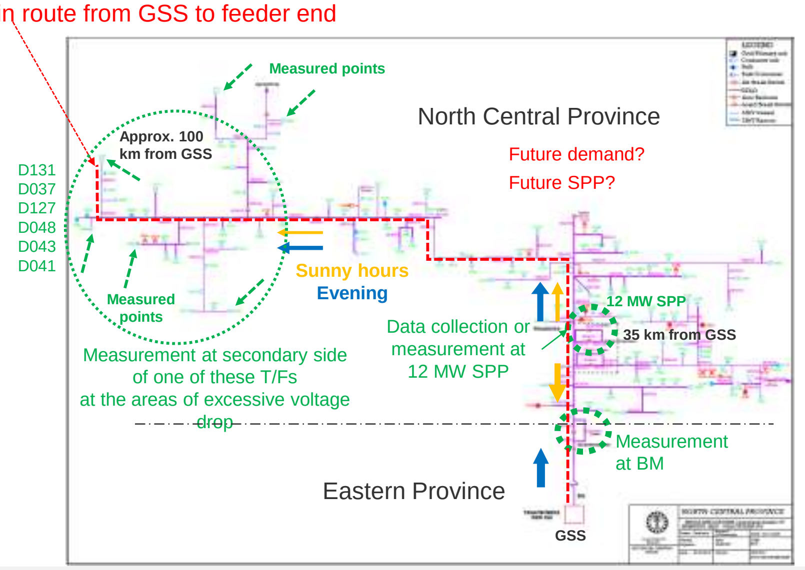
Influence by additional total 3 MW SPPs to be installed in near future?

- DD1 Area -

Measurement in Valachchenai F5 - DD2 Area -

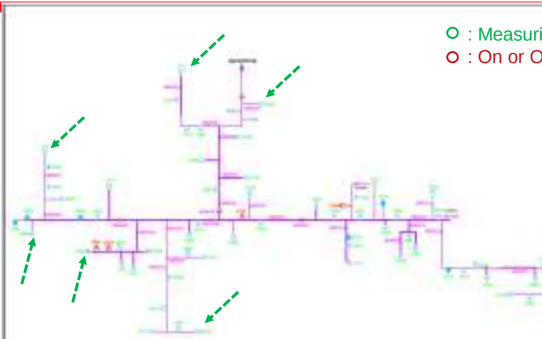
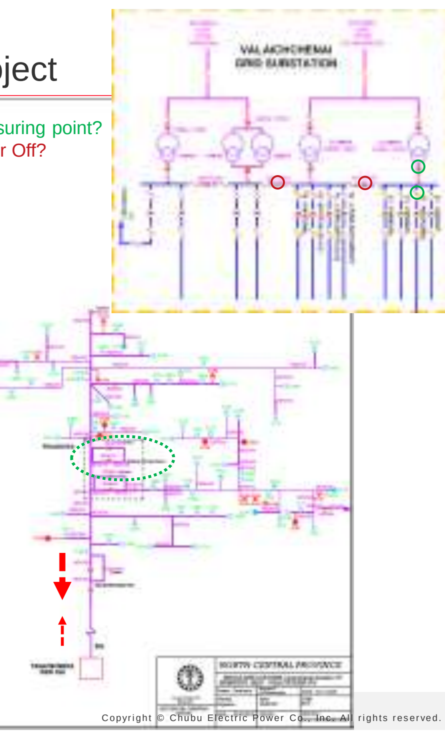


Measurement in Valachchenai F5 - DD1 Area -



Consideration of Capacity and Budget of BESS for a Pilot Project

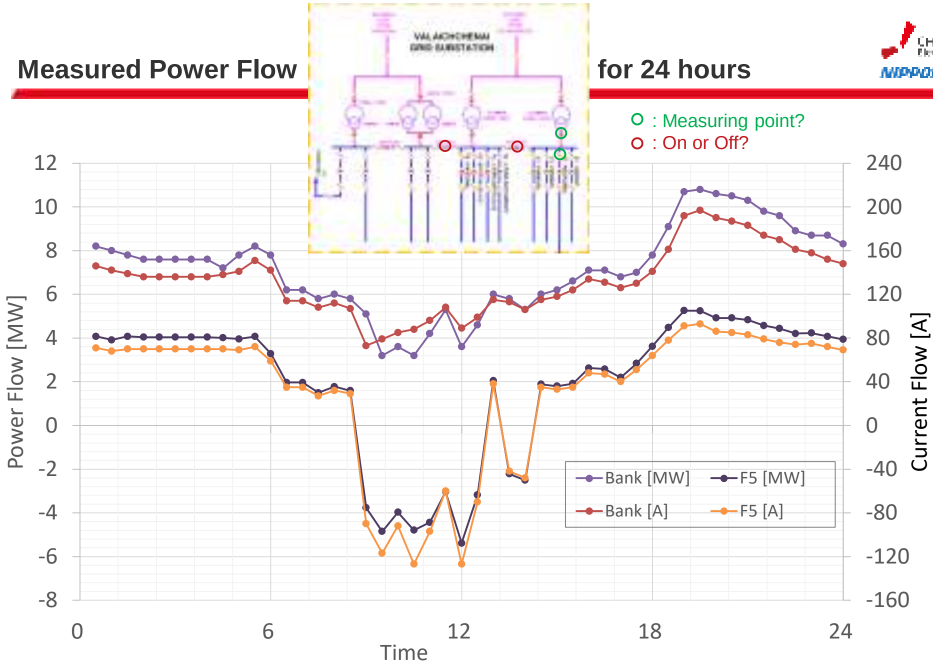
Target MV System for the Pilot Project

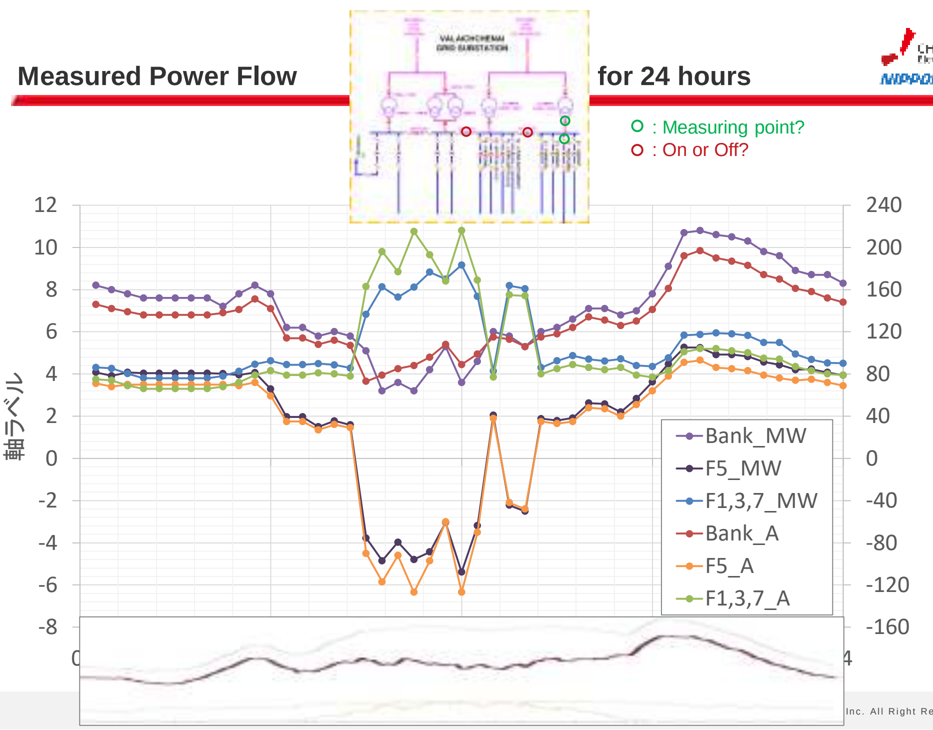
Please provide the following information and data of Valachchena New GSS and its feeders.

- Single line diagram
- GIS information (Layout on map)
- VRE installation data (capacity and location on map)

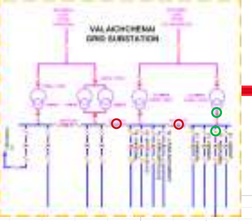
Measured Power Flow for 24 hours

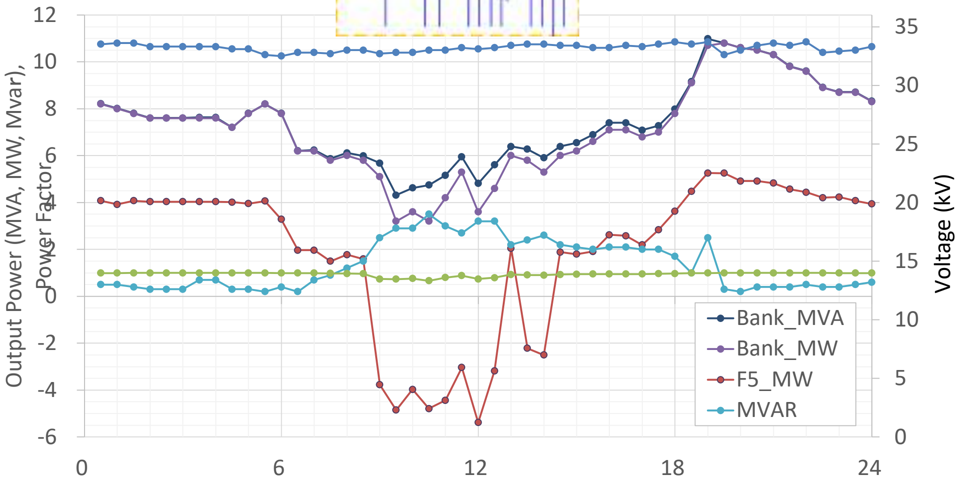


Measured Power Flow for 24 hours



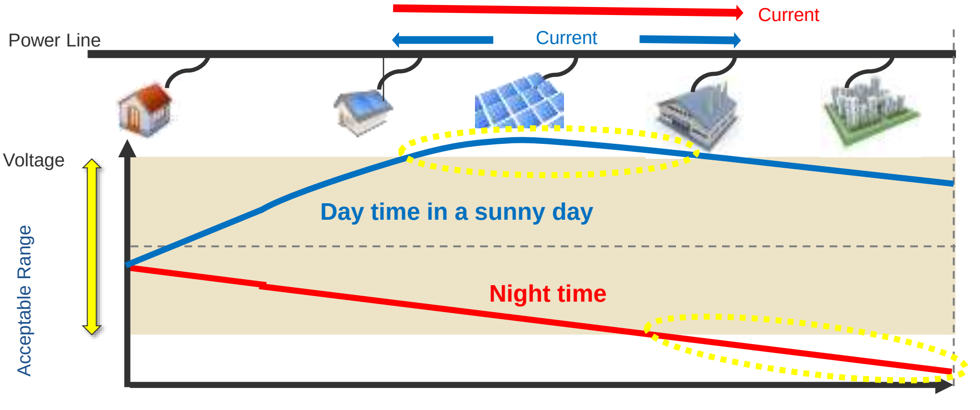
Measured Power Flow for 24 hours



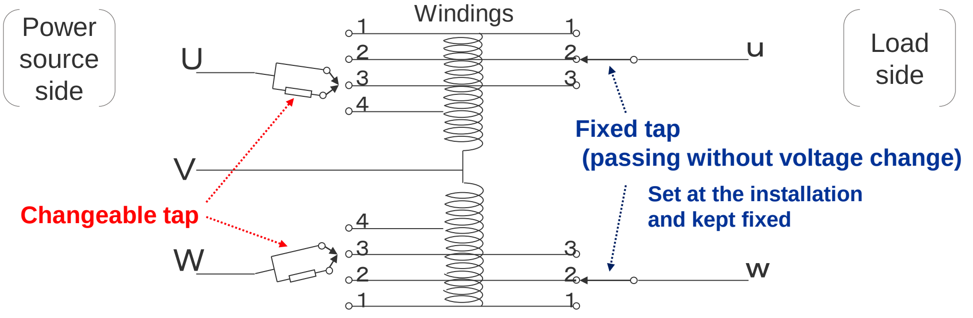


Outline of Dispersal of Distribution Line Voltage

■ Voltage regulation

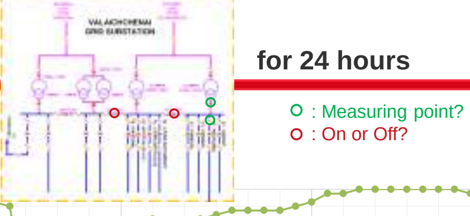


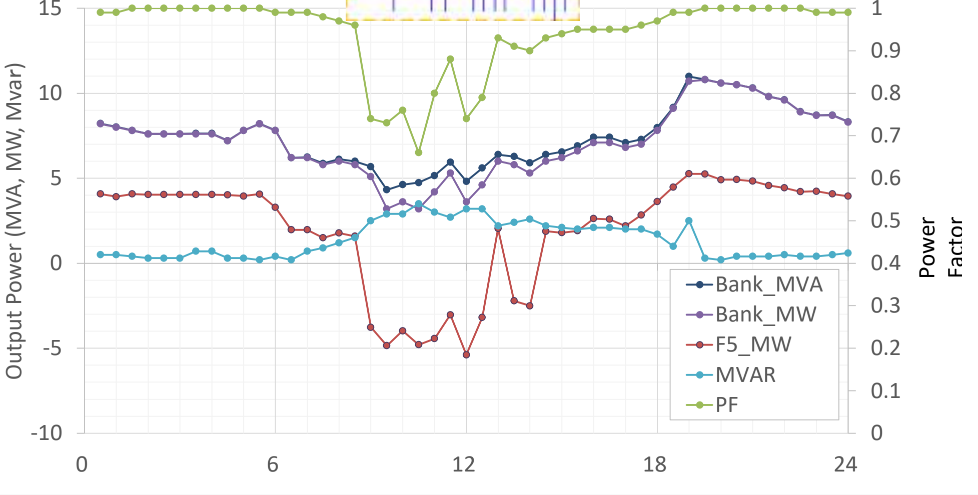
Tap Selection State of MV/LV T/F. How about HV/MV T/F?



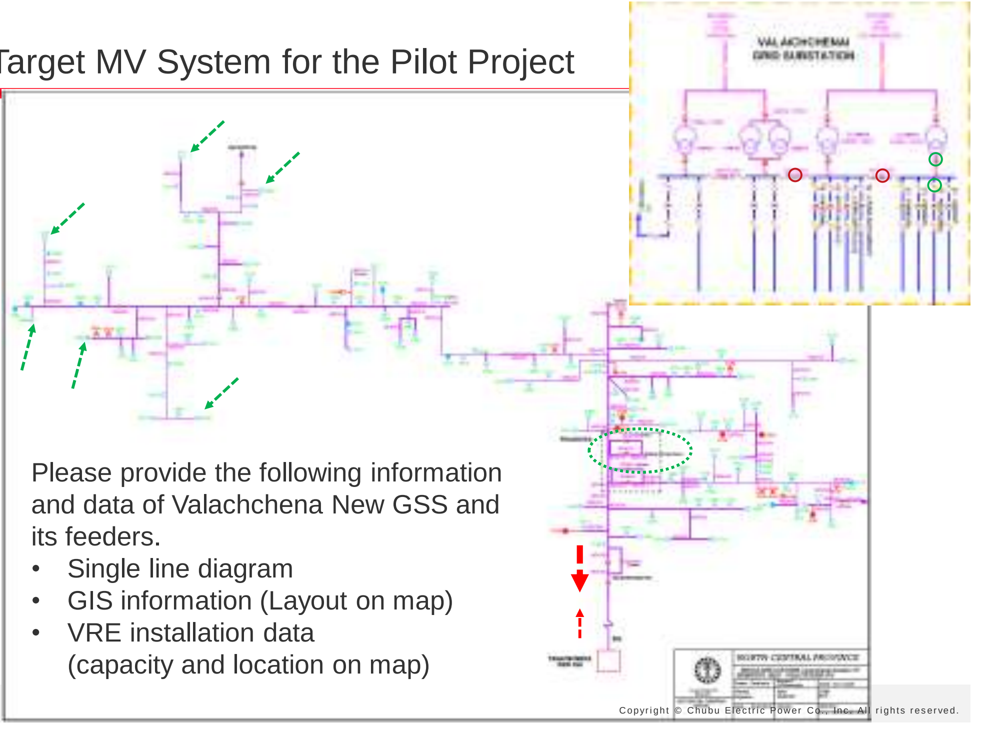
Fixed tap	Changeable tap	Output voltage	Winding ratio (primary/secondary)
2	1	One step down: -150V	6750/6600
	2	No step up/down: 0V	6600/6600 (No step)
	3	One step up: 150V	6450/6600
	4	Two steps up: +300V	6300/6600

Measured Power Flow for 24 hours



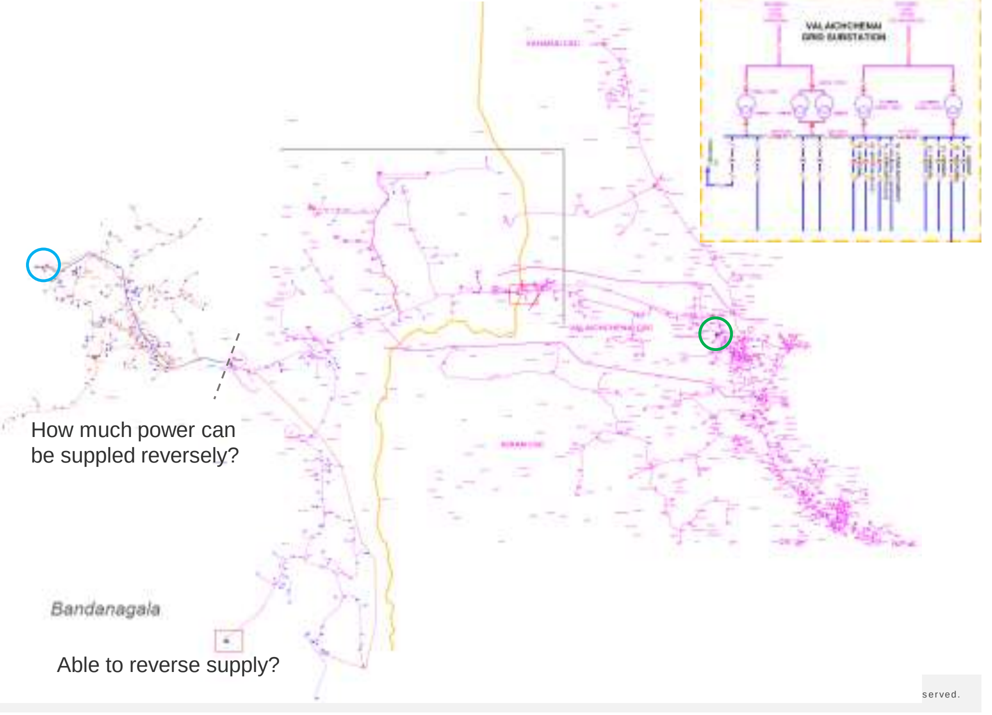


Target MV System for the Pilot Project



Please provide the following information and data of Valachchena New GSS and its feeders.

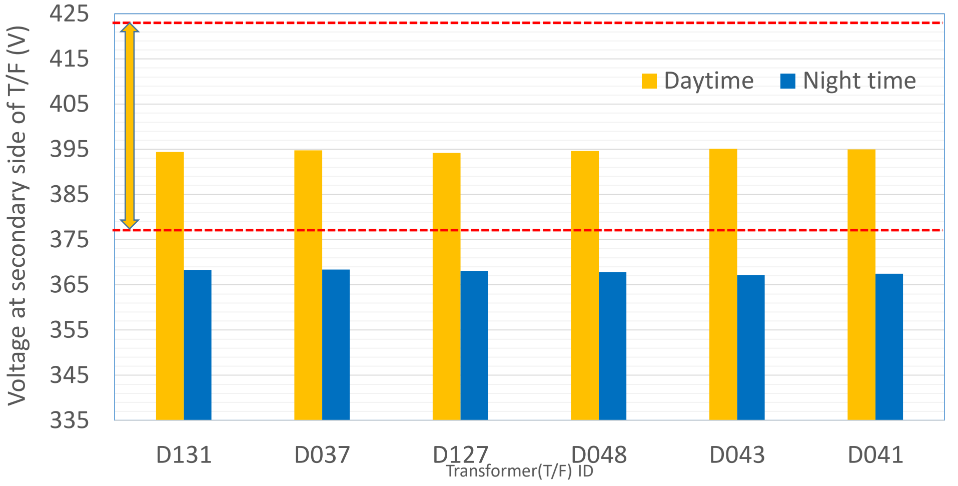
- Single line diagram
- GIS information (Layout on map)
- VRE installation data (capacity and location on map)



How much power can be suppled reversely?

Able to reverse supply?

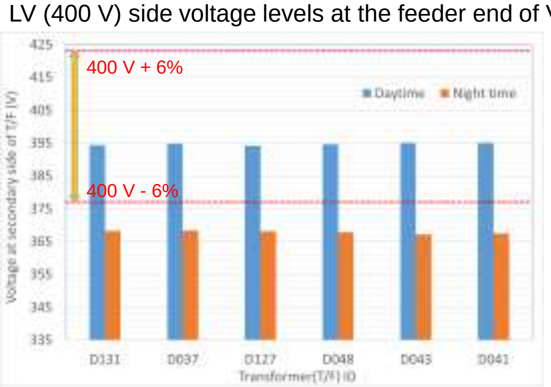
Measured Low Voltage at the Ends of the Valachchenai F5



Which season? Which day(weekday or weekend)? What time at night peak? Which phase (unbalance)?
Which weather (Sunny, cloudy or rainy? How much temperature?)

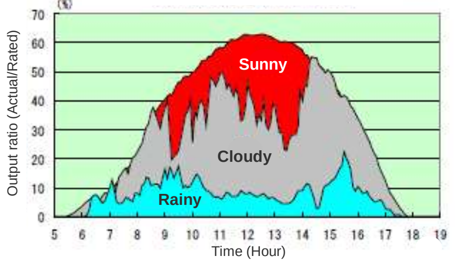
Profiles of Measured Data (Voltage)

LV (400 V) side voltage levels at the feeder end of Valachchena Feeder 05



Transformer Identification No.	Daytime	Night time
D131	394.4	368.3
D037	394.8	368.4
D127	394.2	368.1
D048	394.6	367.8
D043	395.1	367.2
D041	395.0	367.5

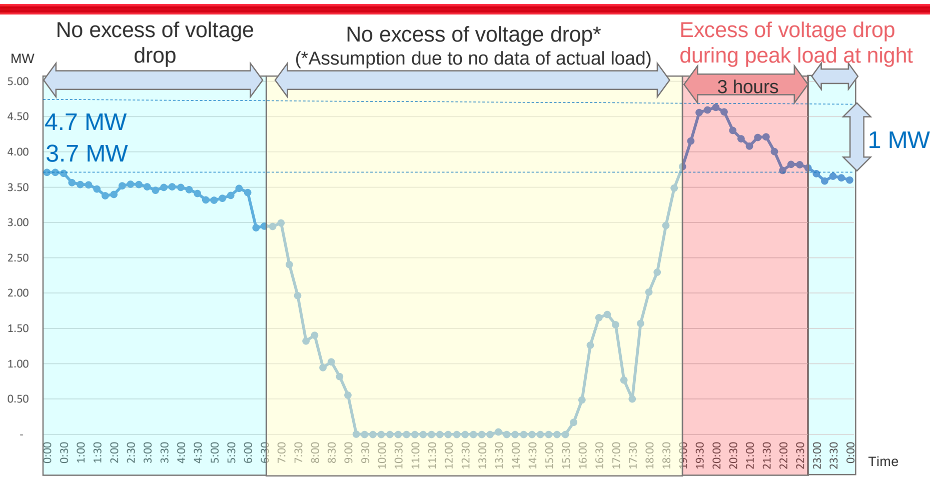
Output power by Solar PV



Each generation curve of sunny, cloudy and rainy days is helpful to analyze solar PV generation, as output power generated by PV is not stable due to the weather conditions such as solar radiation conditions.

Which season? Which day(weekday or weekend)? What time at night peak? Which phase (unbalance)?
Which weather (Sunny, cloudy or rainy? How much temperature?)

Consideration of Storage Battery System Budget



Cost estimation associated with capacity change of storage battery system
- Initial estimation of capacity: 100kW class for 0.5 hour class
- Estimation of Valachchenai F5: 1MW class for 3 hours (roughly 4 million USD)

Selection of Target Feeder

to Measure and Analyze Output Power/Voltage

Target Feeders to Measure and Analyze Power/Voltage

Previous selection of the target feeders by each DD to survey problems by mass VRE introduction

DD LECO	Province	Area	Substation	2ndary kV	Feeder [Name]	Remarks
DD1	NCP	Minneriya	Polonnaruwa	33	Walikanda	
	NWP	Puttalam	Norochcholei Wind		F2	Kalpitaya WP 12x0.85MW, Senok WP 8x1.25MW
DD2	WPN	Gampaha	Sapugaskanda		F0	
	WNP	Veyangoda	Veyangoda		F8	
DD3	WPS2		Panadura		F1	
			Pannipitiya		F4	
			Horana		F4	
			Horana		F6	
DD4	SP	Hambantota	Hambantota	33	F2	
	SP	Hambantota	Hambantota	33	F4	
	WPS1	Kalutara	Panadura	33	F07	
	WPS1	Kalutara	Panadura	33	F08	

	Developer Name	Solar Plant Name	Capacity	Location		
			(MW)	Connected GSS	Latitude	Longitude
1	Japan Solar Plant (SEA)	Gonnoruwa Phase I SPP	0.737	**Hambanthota**	6°13'31.31"N	81°4'38.07"E
2	Korean Solar Plant (SEA)	Gonnoruwa Phase II SPP	0.5	**Hambanthota**	6°13'34.94"N	81°4'31.86"E
3	Saga Solar	Saga (Baruthankanda) SPP	10	**Hambanthota**	6°13'53.59"N	81°5'8.85"E
4	Iris Eco Power Lanka (Pvt) Ltd	Iris (Baruthankanda) SPP	10	**Hambanthota**	6°13'57.19"N	81°4'43.77"E
5	Anorchi Lanka (Private) Ltd	Anorchi Lanka (Baruthankanda) SPP	10	**Hambanthota**	6°13'39.72"N	81°4'50.40"E
6	Solar One Ceylon (Pvt) Ltd	Solar One Ceylon Power (Pudukadumalai) Solar PV PP	10	**Valachchenai**	7°58'31.22"N	81°14'9.89"E
7	Vydexa (Lanka) Power Corporation (Pvt) Ltd	Nedunkulam Solar PV PP	10	Vauniya	8°46'16.69"N	80°31'40.50"E
	Total		51.237			

Target Feeders to Measure and Analyze Power/Voltage

Target feeder information to measure and analyze

Input the target feeder information to measure and record data.

Organization	DD1, 2, 3, 4, LECO
Province	
Area (District)	
Substation name	
Feeder No.	

Please answer yes or no about the availability of data transmission (communication) network way at the target area.

Class	2G	2.5G	3G	4G	5G	Other way such as optical fiber, CEB own line, OPGW, etc.
Target area						
Substation						
VRE installation						
Feeder end						
Other areas						

Please answer yes or no, according to whether you can presently measure and record the following data at the following points.

Effective value (Root mean square)

Measurement area	Measurement point	Freqency	Power factor	Voltage at each phase			Current at each phase			Apparent power						Active power						Active power					
				R	Y	B	R	Y	B	Forward			Backward			Forward			Backward			Forward			Backward		
										R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B
		Hz		V	V	V	A	A	A	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA
Substation	at the CT and VT terminal in the panel																										
Substation	?																										
VRE installation	secondary side (230V) of the PCS																										
VRE installation	?																										
Feeder end	secondary side (230V) of the 33/0.4kV T/F																										
Feeder end																											
others	?																										
?	?																										
?	?																										

Please select the first target feeder by each DD and LECO to measure output power/voltage.

Instantaneous value (wave form)

Measurement area	Measurement point	Freqency	Power factor	Voltage at each phase			Current at each phase			Apparent power						Active power						Active power						Harmonic
				R	Y	B	R	Y	B	Forward			Backward			Forward			Backward			Forward			Backward			injection
										R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	R	Y	B	at degree n
		Hz		V	V	V	A	A	A	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	VA	%
Substation	at the CT and VT terminal in the panel																											
Substation	?																											
VRE installation	secondary side (230V) of the PCS																											
VRE installation	?																											
Feeder end	secondary side (230V) of the 33/0.4kV T/F																											
Feeder end																												
others	?																											
?	?																											
?	?																											

- It is OK even though there is no matter, as enhancing technical measurement capability is a main purpose.
- How about considering the areas which WG 2 are selecting to forecast VRE output power.

Target Feeders to Measure and Analyze Power/Voltage

Selection of the first target feeder by each DD and LECO to measure output power/voltage.

DD LECO	Province	District/Area	Substation	2ndary [kV]	Feeder [Name]	Remarks
DD1	NCP	Minneriya	Valachchena	33	F05	Load side of the boundary meter
	NCP	Minneriya	Polonnaruwa	33	Walikanda	
	NWP	Puttalam	Norochcholei Wind		F2	Kalpitaya WP 12x0.85MW, Senok WP 8x1.25MW
	CC?	Colombo	?	?	?	CEB head office where WG2 will forecast RT-PV generation
DD2	EP	Batticaloa	Valachchena	33	F05	Power source side of the boundary meter
	WPN	Gampaha	Sapugaskanda		F0	
	WNP	Veyangoda	Veyangoda		F8	
DD3	WPS2		Panadura		F1	
			Pannipitiya		F4	
			Horana		F4	
			Horana		F6	
	WPS2	Sri J'pura	Ethulkotte PSS	11	F4	Not far from head office where WG2 will forecast RT-PV generation
	~~WPS2~~	~~Sri J'pura~~	~~?~~	~~?~~	~~?~~	~~CEB DD3 office where WG2 will forecast RT-PV generation~~
DD4	SP	Hambantota	Hambantota	33	F2	
	SP	Hambantota	Hambantota	33	F4	
	WPS1	Kalutara	Panadura	33	F07	
	WPS1	Kalutara	Panadura	33	F08	
LECO	WP?	Gampaha	Seeduwa	11	Katunayaka	Many problems in LV lines by solar PV generation?

After measuring and recording, it will be analyzed whether there are any problems such as power flow excess, over/under voltage, flicker, instantaneous voltage dip, harmonics. If any, how much level?

Target Feeders to Measure and Analyze Power/Voltage

Selection of the first target feeder by each DD and LECO to measure output power/voltage.

DD LECO	Province	District/ Area	Voltage [kV]	Substation	Measuring sites	Remarks
DD1	NCP	Minneriya	132/33	Valachchena	F5	DD1: Load side DD2: Power source side of the boundary meter Solar One Ceylon Power in Pudukadumalai is forecasted by WG2.
DD2	EP	Batticaloa				
DD3	WPS2	Sri J'pura	33/11	Ethulkotte PSS	LV line in F4	LV line side of T/F: TL007(D) Refer to forecasted RT-PV generation at CEB head office
DD4	SP	Hambantota?	132/33?	Hambantota?	LV line	LV line side of T/F: RR3 SAGA Solar Power is forecasted by WG2.
LECO	WP	Gampaha	33/11	Seeduwa	LV line in Katunayaka	2ndary side of a T/F Many problems in LV lines by solar PV generation Approx. 25 km far from CEB head office

After measuring and recording, it will be analyzed whether there are any problems such as power flow excess, over/under voltage, flicker, instantaneous voltage dip, harmonics. If any, how much level?

Target Feeders to Measure and Analyze Power/Voltage

Selection of the first target feeder by each DD and LECO to measure output power/voltage.

	Province	District/Area	Substation	Feeder	Remarks
DD1	NCP	Minneriya	132/33 kV Valachchenai	F5	<DD1> Feeder end side of the boundary meter <DD2> GSS side of the boundary meter SPP2 (Solar One Ceylon Power generation) in Pudukadumalai forecasted by WG2 can be referred.
DD2	EP	Batticaloa			
DD3	WPS2	Sri J'pura	33/11 kV Ethulkotte	F4	T/F: TL007(D) RT-PV forecast by WG2 at CEB HQ (SPP5), not far from TL007 may be referred.
DD4	~~SP~~ WP	~~Hambantota~~ Colombo	~~Hambantota~~ 132/33 kV? Ratmalana	~~F2 or F4~~ F7	T/F: Which transformer with many VRE in LV line? SAGA Solar Power (SPP3) forecast by WG2 may be referred.
LECO	WP	Gampaha	33/11 kV Seeduwa	Katunayaka	T/F: Many problems in LV lines by RT-PV generation RT-PV forecast by WG2 at CEB HQ (SPP5), approx. 25km far from Katunayaka, can be referred.

After measuring and recording, it will be analyzed whether there are any problems such as power flow excess, over/under voltage, flicker, instantaneous voltage dip, harmonics. If any, how much level?

Preparation for

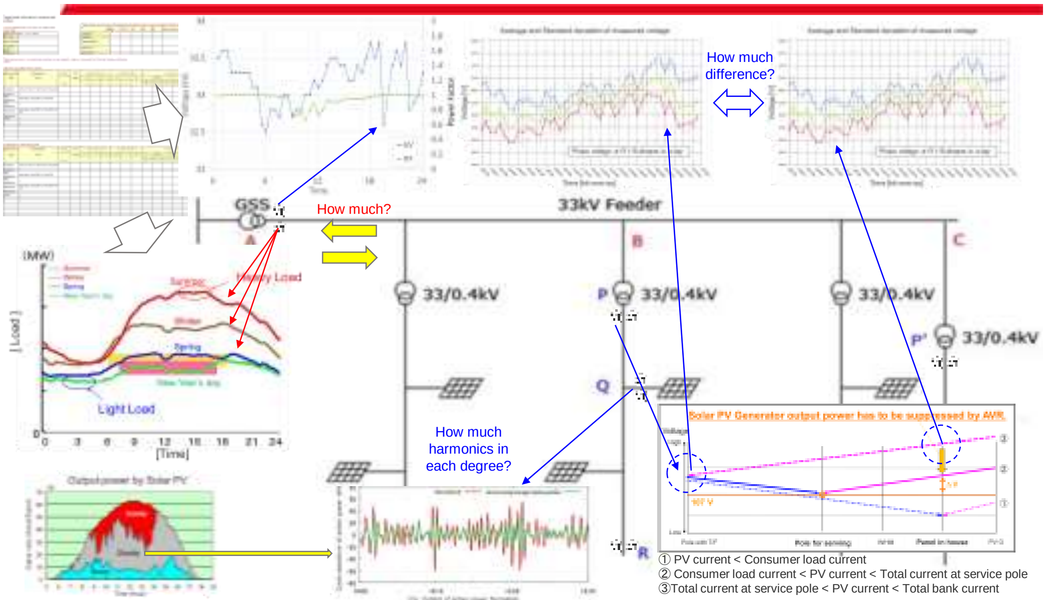
measurement of the Target Feeder

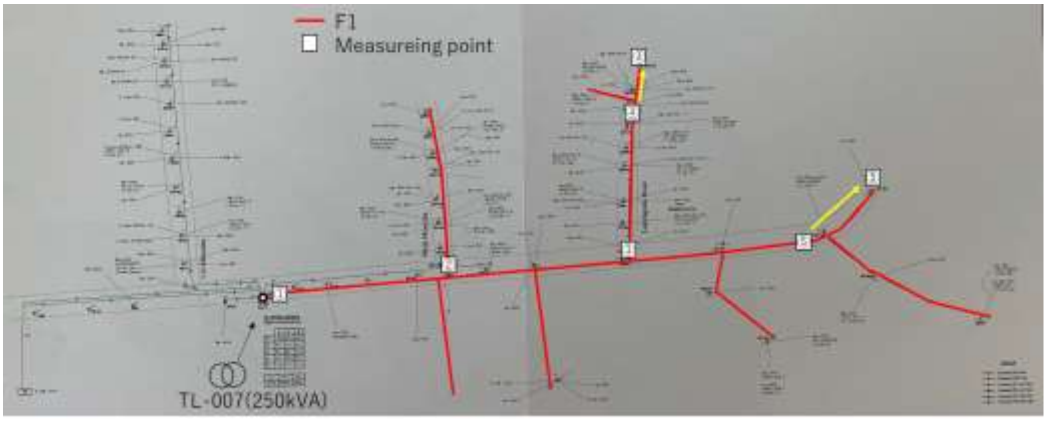
Preparation for Measurement

- Check the necessary procedures for measurement at the target sites such as GSS
- Consider how to measure output power/voltage at GSS and VRE connection site
- Confirm the operating conditions, etc. of LRT at S/S to measure power/voltage curves for 24 hours on weekday and weekend later.
- Preparation for the first survey at the measuring points in advance

*Electric Power Measuring Instrument	Organization	Quantity [pcs]	Responsibility person	Person to handover			Expected delivery
				Name	TEL	Email	
Clamp on power logger  	DD1	1	Sub-leader?				Tentatively, End of DEC, 2021
	DD2	1	Sub-leader?				
	DD3	1	Sub-leader?				
	DD4	1	Sub-leader?				
	LECO	1	Sub-leader?				
Power quality analyzer	DD4?	1	Leader?				

Data Records by Measuring and Analyzing Power/Voltage





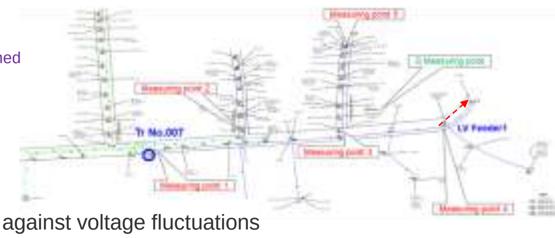
Location of the Target LV Feeder 01 of TL-007 Transformer

Supplied by Ethulkotte PSS Feeder 04

Parliament

WG 3-2: Activities to Achieve the Targets

- Collect the connected load and generation capacities along the feeder and their monthly consumption.
- Measure power/voltage fluctuation at rooftop solar-PV generators of residential prosumers.
  - Generation curves in sunny, cloudy(obtained) and rainy days
- Measure power/voltage fluctuation at the outgoing point(obtained), two major branching points, two end points.
  - Load-generation combined fluctuations for 24 hours at both weekday and weekend obtained
- Check the connection phase of 1ϕ consumers to estimate phase unbalance more exactly (Obtained).

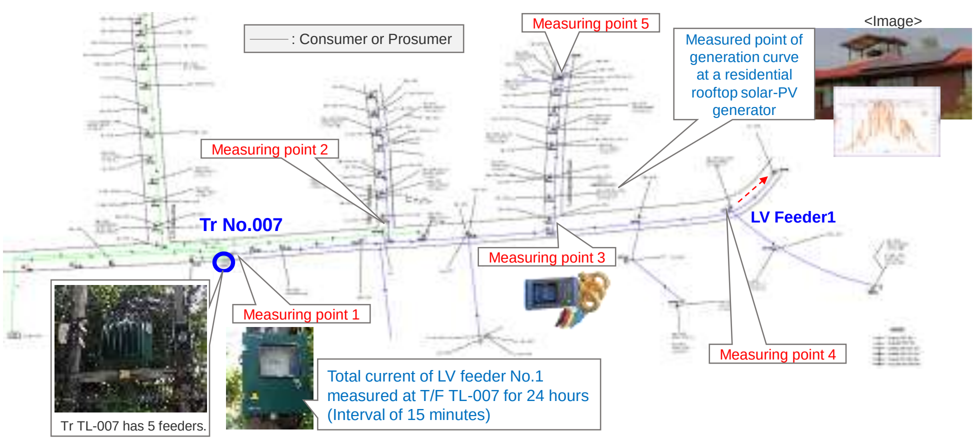


- Consider suppression way such as BESS and conventional countermeasures against voltage fluctuations
- Estimate and compare their suppression effects against voltage fluctuation by the prepared model.
- **Share the results and knowledge one another**

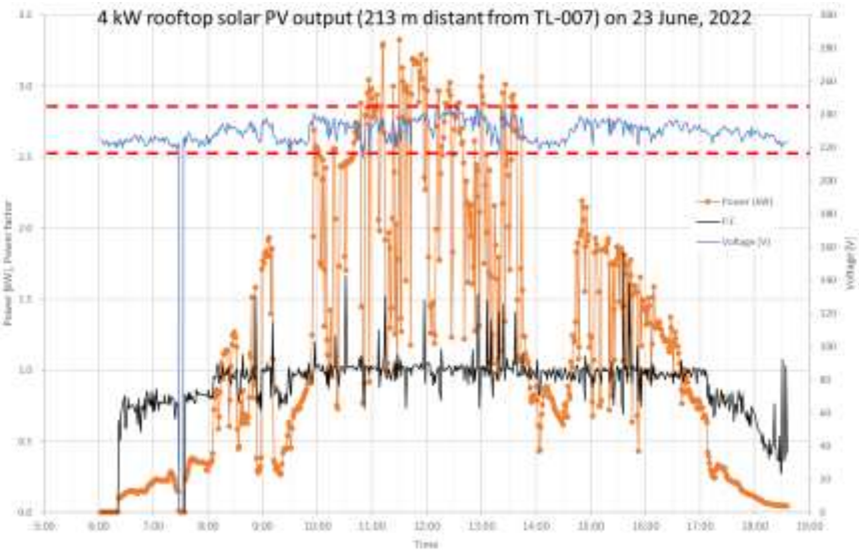
Measurement of LV Voltage/Current at the Target Site

- Measure and analyze the voltage fluctuation in **No.1 LV feeder of TL-007 transformer in Ethulkotte** to estimate cost effectiveness comparison between BESS and conventional countermeasures.
  - Most of necessary data and information were obtained for modeling and analyze.
  - Measurement data are being prepared to estimate load fluctuation.

Lots of DER (residential rooftop solar PV generators) are interconnected to the LV feeder No.1.



Solar-PV Generation Curve1 by Residential at the TL-007 F1



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Solar-PV Generation Curve 2 by Residential at the TL-007 F1

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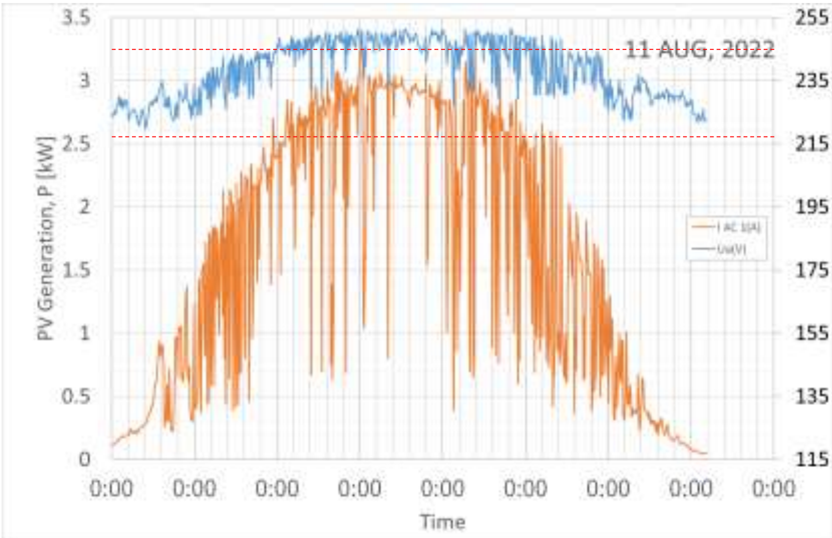
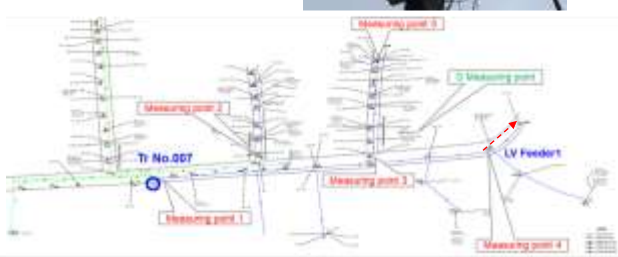
Solar-PV Generation Curve 3 by Residential at the TL-007 F1

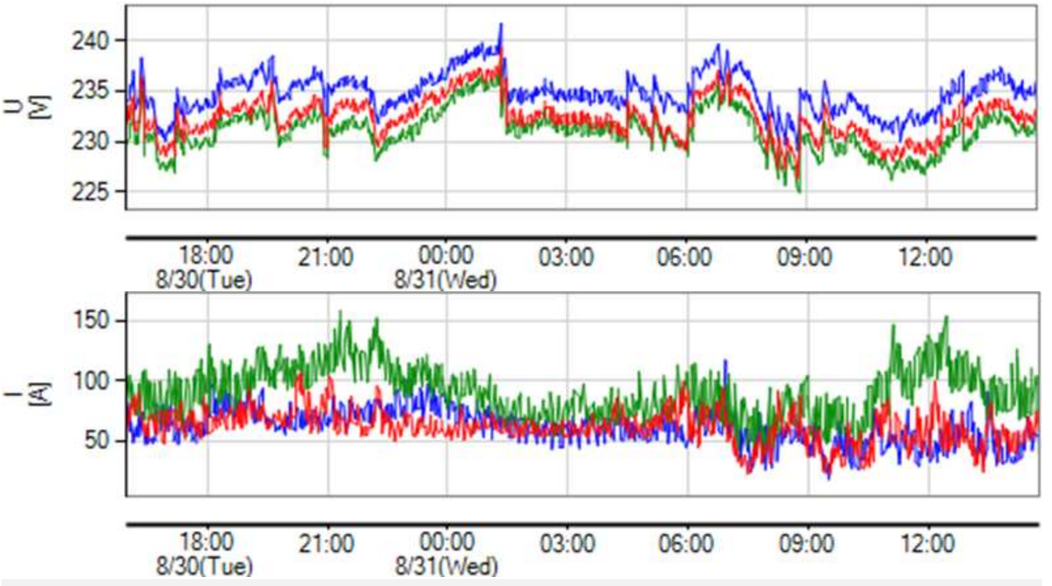


Measurement of Power/Voltage at the TL-007 F1

VI measurement instruments
in a box on pole
in a rainy day



Measured Voltage/Current at the TL-007 F1



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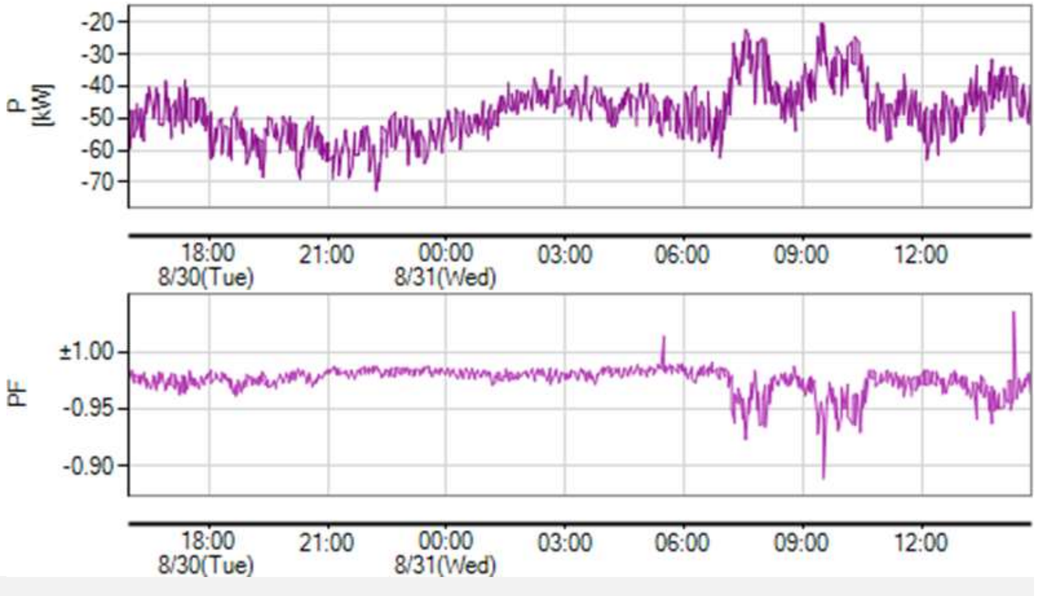
Measured Power/Power factor at the TL-007 F1



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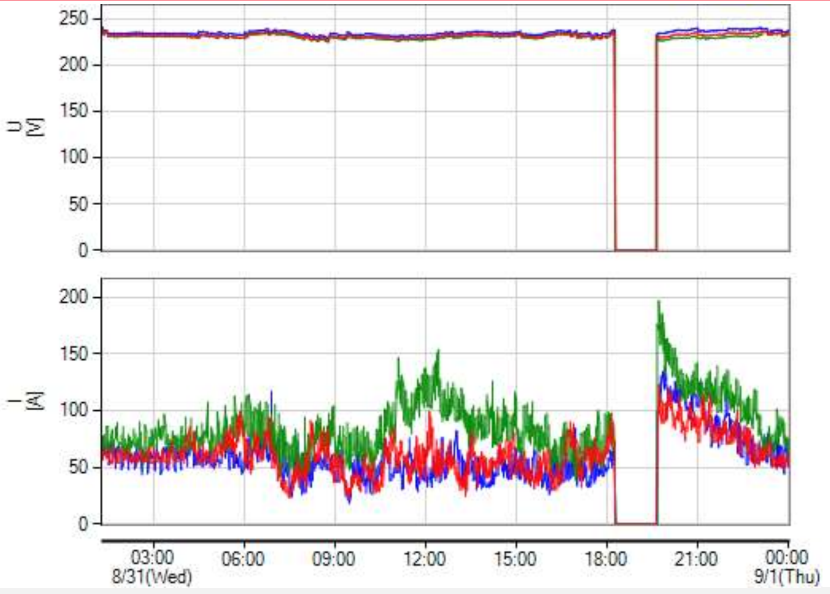
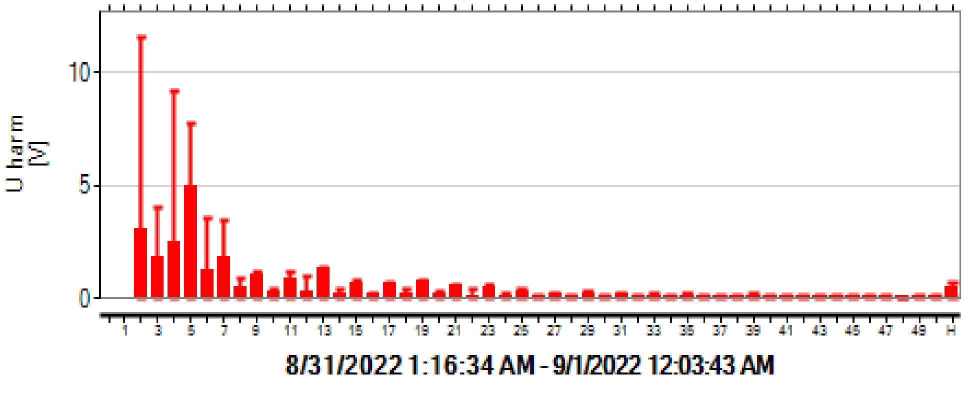
Measured Voltage/Current at the TL-007 F1



Harmonics - Peak Level(0 - 50th) at the TL-007 F1

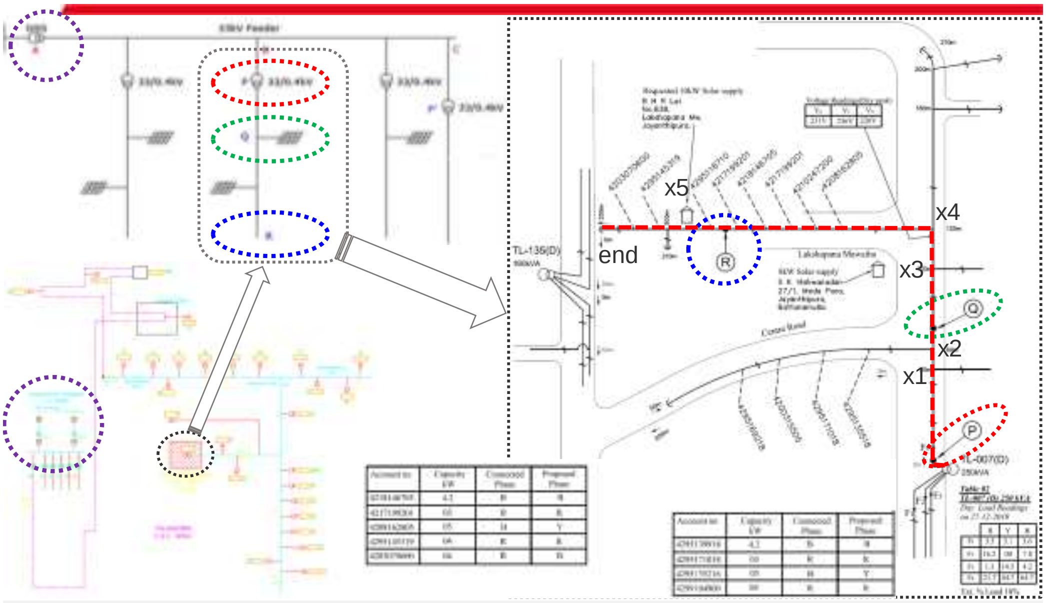


Modeling of Target Feeder

to Measure and Analyze Output Power/Voltage

- Low Voltage Feeder -

Target LV Feeder with VRE - DD3 Area -



他の低圧配電線の例

CHUBU Electric Power / NIPPON KOEI

Table: Information of SPP interconnected to LV line

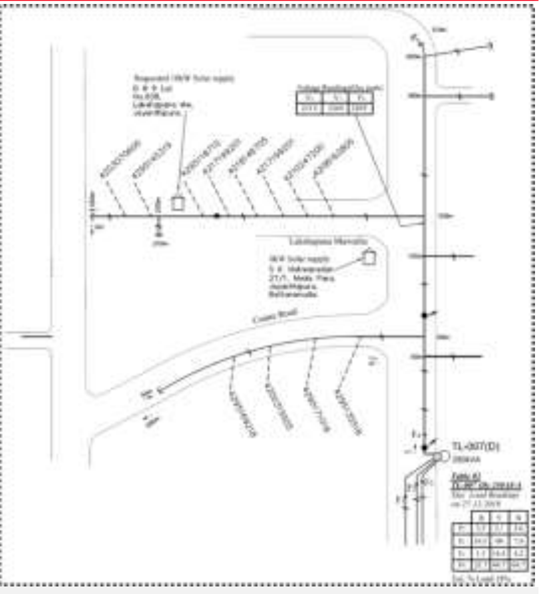
Account no	Capacity kW	Connected Phase	Proposed Phase
4218146705	4.2	B	B
4217199201	03	R	R
4208162805	05	B	Y
4295145319	04	R	R
4203070600	04	R	B
4295139918	4.2	B	B
4295171018	03	R	R
4295135216	05	B	Y
4299104900	04	R	R

Customer ID

PV generation capacity

(applied)

(recommended)



Modeling of LV Feeder with VRE

CHUBU Electric Power / NIPPON KOEI

Modeling of distributed load and VRE and facility information (line constant, etc.)

Necessity of connecting phase information (R, B, Y)

TL-007(D) F4 Load ratio 18% G ratio 80%

Main route			Load			Generator		Remarks	Line specifications			
S/S side	MV line end side	Length	Load	Total Tr (load) capacity	Load ratio [(SS load) /(Total Tr capacity)]	VRE capacity	Generation capacity	Solar PV specifications, etc.	Wire type	Wire size	Resistance, R	Reactance, X
(Grid power source side)	(Connection point)	m	kW	kW	kW	kW	kW	-	-	mm^2	ohm/km	ohm/km
TL-007(D)	P			23.2	4.2		0.0					
P	x1			23.2	4.2		0.0					
x1	x2		3.0	23.2	4.2		0.0					
x2	Q			20.2	3.6		0.0					
Q	x3			20.2	3.6		0.0					
x3	x4			20.2	3.6		0.0					
x4	4208162805		5.0	20.2	3.6		0.0					
4208162805	4210247200			15.2	2.7		0.0					
4210247200	4217199201		3.0	15.2	2.7		0.0					
4217199201	4218146705		4.2	12.2	2.2		0.0					
4218146705	R			8.0	1.4		0.0					
R	4295118710			8.0	1.4		0.0					
4295118710	B H R Lai No. 838			8.0	1.4	10.0	8.0					
B H R Lai No. 838	x5			8.0	1.4		0.0					
x5	4295145319		4.0	8.0	1.4		0.0					
4295145319	4203070600		4.0	4.0	0.7		0.0					
4203070600	end			0.0	0.0		0.0					

- DD3 Area -

Modeling of the TL-007 LV F1

CHUBU Electric Power
NIPPON KOEI

Pole span | LV line specifications | Customer load consumption | Solar-PV generation | Mix of consumption and generation

Pole number at S/S side of LV line span	Pole ID at end side of LV line span	Length (Pole span)	LV line (wire) number	Wire type	Wire size of 3-phase	Resistance of 3-phase, R3	Reactance of 3-phase, X3	Wire size of neutral	Resistance of neutral, R	Reactance of neutral, X	Customer number of 1-phase at end side pole	Customer number of 3-phase at end side pole
		m	2,3,4,---	Cu, Al, etc.	mm^2	ohm/km	ohm/km	mm^2	ohm/km	ohm/km		
TL-007(D)	P	0	4	Cu		0.5781	0.4695					
P	A1	16	0	ABC(Al)		0.5781	0.4695					
A1	A2	5	1	ABC(Al)		0.5781	0.4695					
A2	A3	41	1	ABC(Al)		0.5781	0.4695				17	
A3	B0	11	1	ABC(Al)		0.5781	0.4695					
B0	A4	36	1	ABC(Al)		0.5781	0.4695					1
A4	A5	31	3	ABC(Al)		0.5781	0.4695					2
A5	A6	21	1	ABC(Al)		0.5781	0.4695					2
A6	A7	37	1	ABC(Al)		0.5781	0.4695					1
A7	A8	30	1	ABC(Al)		0.5781	0.4695				1	
A8	A9	34	1	ABC(Al)		0.5781	0.4695				1	
A8	A10	24	1	ABC(Al)		0.5781	0.4695				0	2
A10	A11	37	2	ABC(Al)		0.5781	0.4695				0	3
A7	A12	8	1	ABC(Al)		0.5781	0.4695				1	1
A12	A13	18	2	ABC(Al)		0.5781	0.4695				1	2
A5	A14		6	ABC(Al)		0.5781	0.4695				7	1
A6	A15	14	1	ABC(Al)		0.5781	0.4695				1	1
A15	A16	38	2	ABC(Al)		0.5781	0.4695				1	3
A16	A17	42	5	ABC(Al)		0.5781	0.4695				3	2
A17	A18	30	5	ABC(Al)		0.5781	0.4695				2	4
A18	A19	24	4	ABC(Al)		0.5781	0.4695				3	2
A19	A20	29	3	ABC(Al)		0.5781	0.4695				2	2
A20	A21	26	4	ABC(Al)		0.5781	0.4695				1	4
A21	A22	29	7	ABC(Al)		0.5781	0.4695				2	4
B0	B1	32	1	ABC(Al)		0.5781	0.4695				1	0
B1	B2	45	2	ABC(Al)		0.5781	0.4695				2	0
B2	B3	45	9	ABC(Al)		0.5781	0.4695				5	4
B3	B4	13	4	ABC(Al)		0.5781	0.4695				1	3
B4	B5	25	2	ABC(Al)		0.5781	0.4695				1	1
B5	B6	17	6	ABC(Al)		0.5781	0.4695				3	3
B6	B7	40	6	ABC(Al)		0.5781	0.4695				4	2
B7	B8	41	1	ABC(Al)		0.5781	0.4695				1	0

Pole ID	a) Contract capacity R (A)	Y (A)	B (A)	a) Contract capacity 3 (A)	Total contract capacity R (A)	Y (A)	B (A)	Total contract capacity (kW)	Power demand R (A)	Y (A)	B (A)	Power demand 3 (A)
P	0	0	0	0	546	360	570	1,524	27	18.0	29	76.
A1	0	0	0	0	546	360	570	1,524	27	18.0	29	76.
A2	0	0	0	0	546	360	570	1,524	27	18.0	29	76.
A3	210	150	150	0	546	360	570	1,524	27	18.0	29	76.
B0	0	0	0	0	336	210	420	1,524	16.8	10.5	21.0	76.
A4	0	0	0	60	210	210	420	1,230	10.5	10.5	21.0	61.
A5	30	0	30	60	210	210	420	1,170	10.5	10.5	21.0	58.
A6	0	0	0	60	120	210	240	1,080	6.0	10.5	12.0	54.
A7	0	0	0	60	30	30	60	300	1.5	1.5	3.0	15.
A8	0	30	0	0	0	30	30	150	0.0	1.5	1.5	7.
A9	0	0	30	0	0	0	30	0	0.0	0.0	1.5	0.
A10	0	0	0	60	0	0	0	150	0.0	0.0	0.0	7.
A11	0	0	0	90	0	0	0	90	0.0	0.0	0.0	4.
A12	0	0	30	30	30	0	30	90	1.5	0.0	1.5	4.
A13	30	0	0	60	30	0	0	60	1.5	0.0	0.0	3.
A14	60	0	150	30	60	0	150	30	3.0	0.0	7.5	1.
A15	30	0	0	60	90	180	180	720	4.5	9.0	9.0	36.
A16	0	30	0	90	60	180	180	660	3.0	9.0	9.0	33.
A17	30	60	0	60	60	150	180	570	3.0	7.5	9.0	28.
A18	0	0	60	120	30	90	180	510	1.5	4.5	9.0	25.
A19	0	30	60	60	30	90	120	390	1.5	4.5	6.0	19.
A20	0	0	60	60	30	60	60	330	1.5	3.0	3.0	16.
A21	30	0	0	120	30	60	0	270	1.5	3.0	0.0	13.
A22	0	60	0	150	0	60	0	150	0.0	3.0	0.0	7.
B1	7	[illegible]	[illegible]	0	126	0	0	294	6.3	0.0	0.0	14.
B2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Customer RE: Customer number of 1-phase at end side pole	Customer number of 3-phase at end side pole	Customer ID, etc. connected to LV line at end side pole, if needed.	Remarks: Solar PV specifications, etc., if needed.	RE facility capacity (kVA)	RE facility capacity (kVA)	Total contract capacity (kW)	Total contract capacity (kW)	Generating amount at peak (kW)	Generating amount at peak (kW)	Power factor	Current (A)	Voltage (V)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

V/I load measurement pole
Generation measurement pole

Share of Typical Matter

- Voltage Excess Matter in LV Line -

Requirement for Safe and Stable Supply Reliability in Sri Lanka

■ Allowable Voltage range

- 33/36 kV
- 11/12 kV
- 230/400 V

Classification	Normal	Contingency
33/36 kV	-6% ~ +6%	-10% ~ +10%
11/12 kV	-6% ~ +6%	-10% ~ +10%
230/400 V	-6% ~ +6%	-10% ~ +10%

■ Replacement due to overload

Facility	Loading rate criteria
Distribution line	70% for economy 125% for emergency
Distribution substation	80% for normal ?% for emergency
Primary substation	125% for overloading

■ Harmonics

- Total
- Each

When installing the inverse converter (inverter), set the harmonic outflow current to the followings.

・Total current distortion: 5% or less
・Each current distortion: 3% or less

Preconditions to the Explanation of Voltage Excess Matter - Voltage Regulation Value in Japan -

Ministerial Ordinance for the Enforcement of the Electricity Business Act

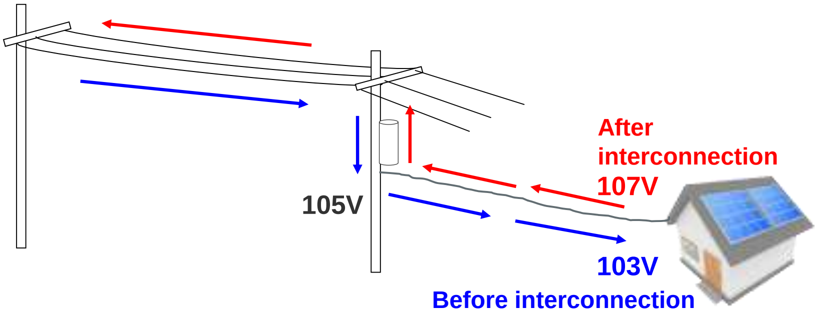
<Article 38>

Standard Voltage	Values to be maintained
100V	101±6V (95 ~ 107 V)
200V	202±20V (182 ~ 222 V)

The voltage value is judged by "30 minutes average value".

Typical Phenomenon by VRE Introduction

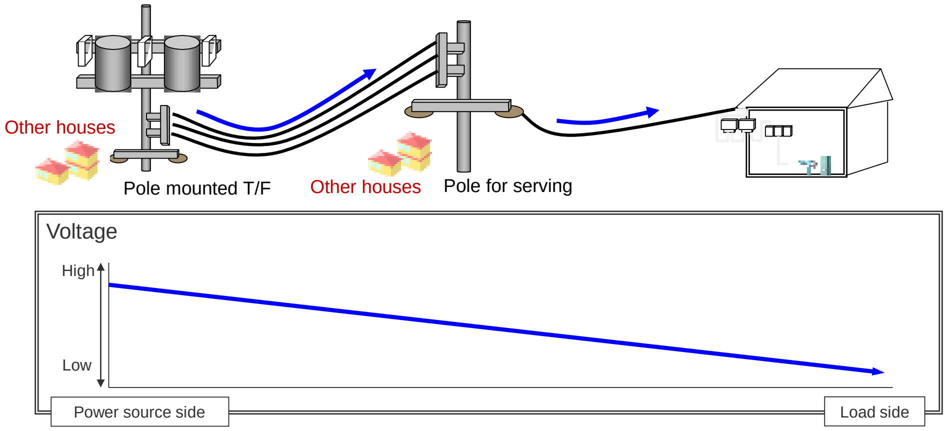
When a distributed power supply source, such as a solar PV(photovoltaic) power generation system installed in a house, is interconnected and supplies power reversely to a LV system, the voltage on the customer side of the service wire becomes higher.



Power Flow without Generator

Electrical property

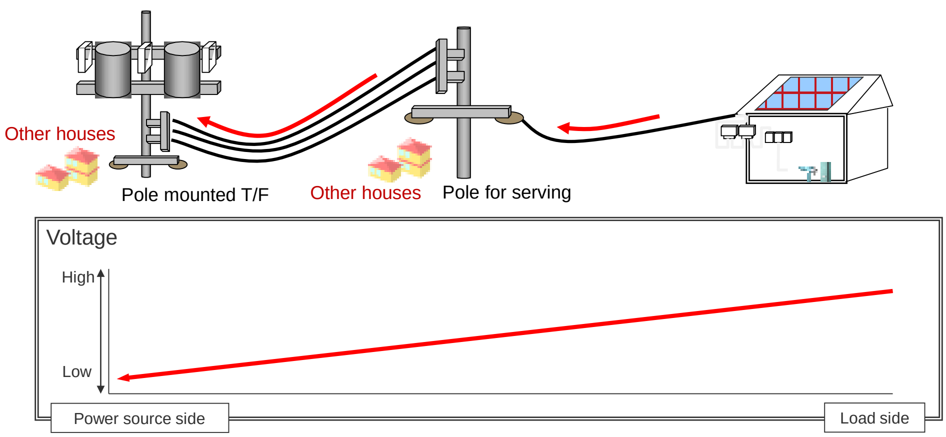
Just as water flows from high to low, electricity has the property of flowing from high (generated side) to low (used side) in voltage.



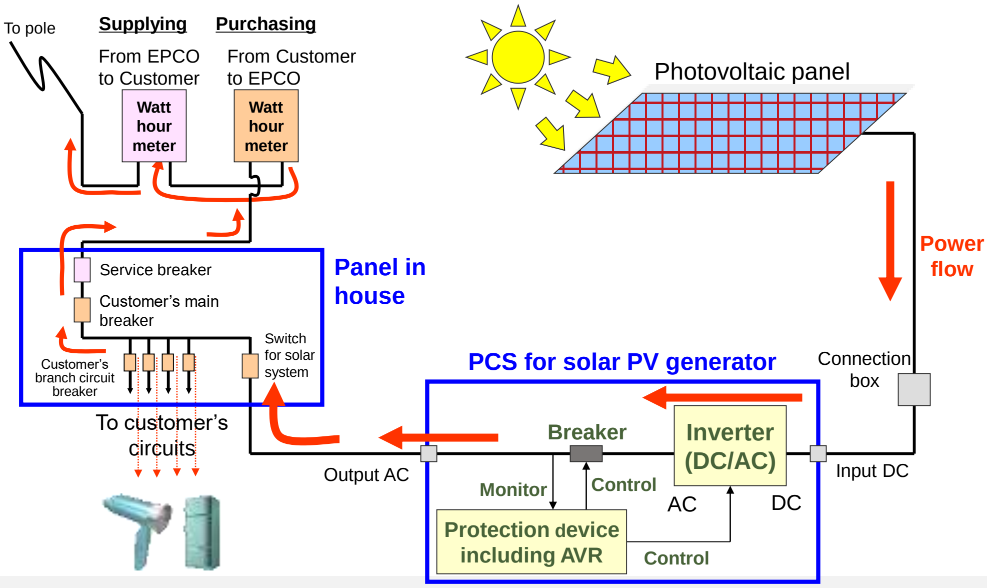
Power Flow with Solar PV Generator

Electrical property

Just as water flows from high to low, electricity has the property of flowing from high (generated side) to low (used side) in voltage.



Consumer Side Circuit and Components with Solar PV Generator

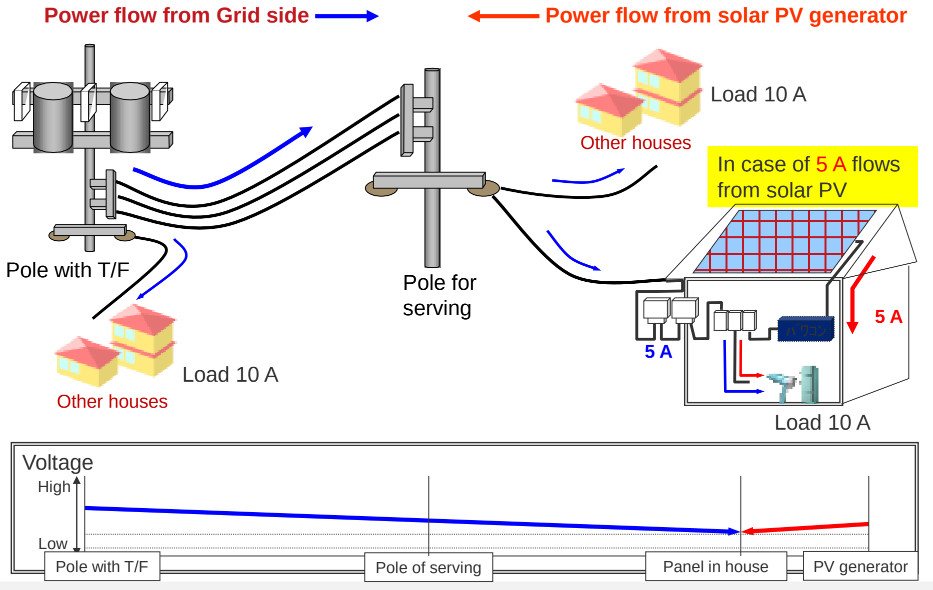


Brief Overview of Solar PV Generation System

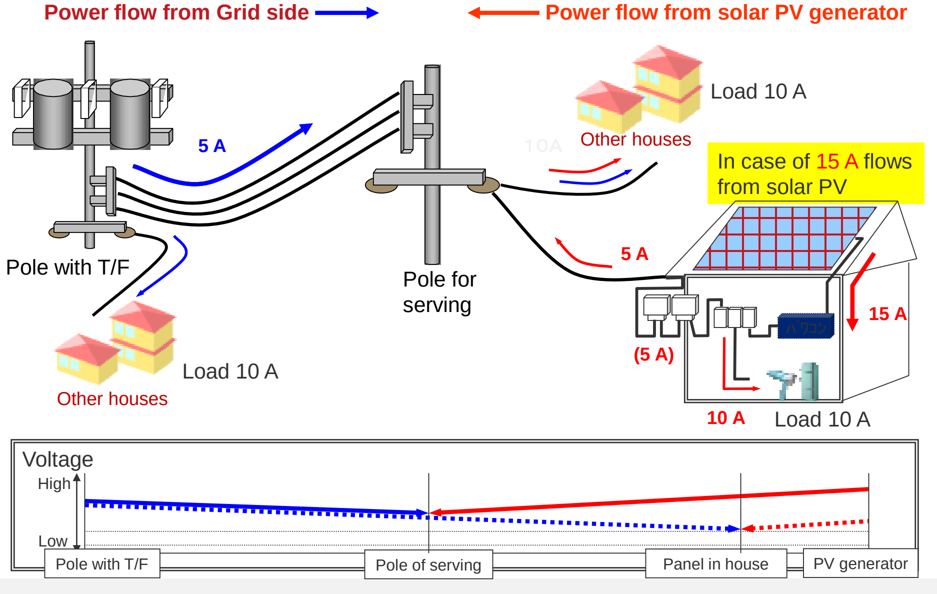
PCS (Power Conditioning System) consists of

- INVERTER
  Convert DC to AC
- PROTECTION DEVICE
  Prevention of islanding
  Control of voltage, current, frequency, etc.
  High quality output by suppressing voltage fluctuation like flicker, harmonics, etc.
- BREAKER
  Stop and disconnect in case of emergency

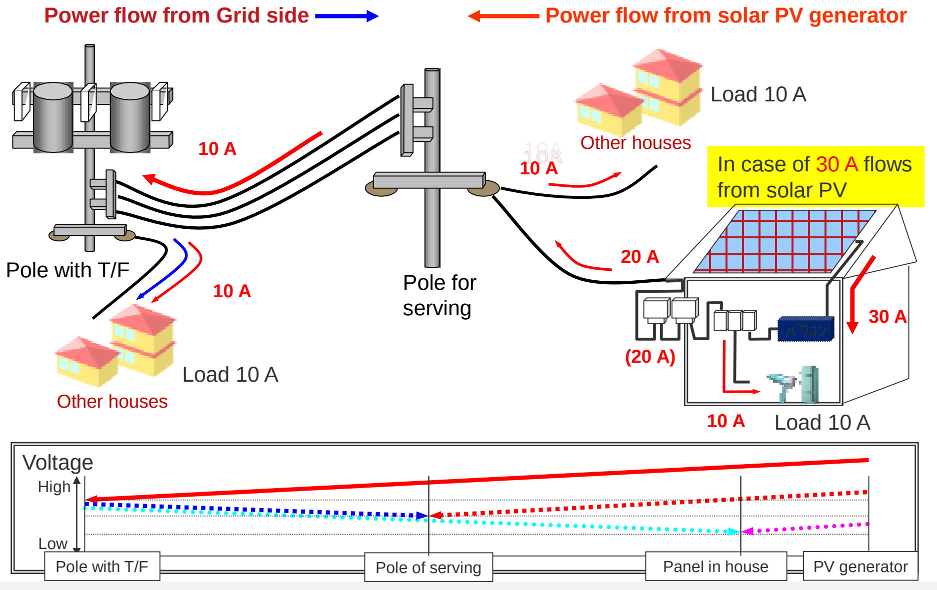
Power Flow with Solar PV Generator



Power Flow with Solar PV Generator

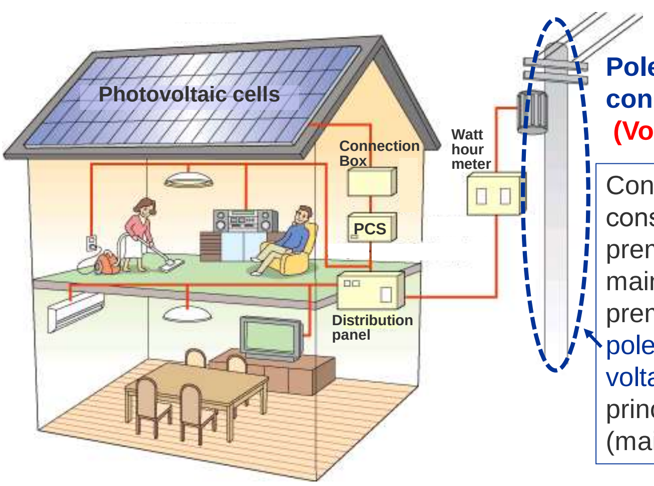


Power Flow with Solar PV Generator



Consideration of Voltage Fluctuation on Application

Voltage Regulation Point and Value



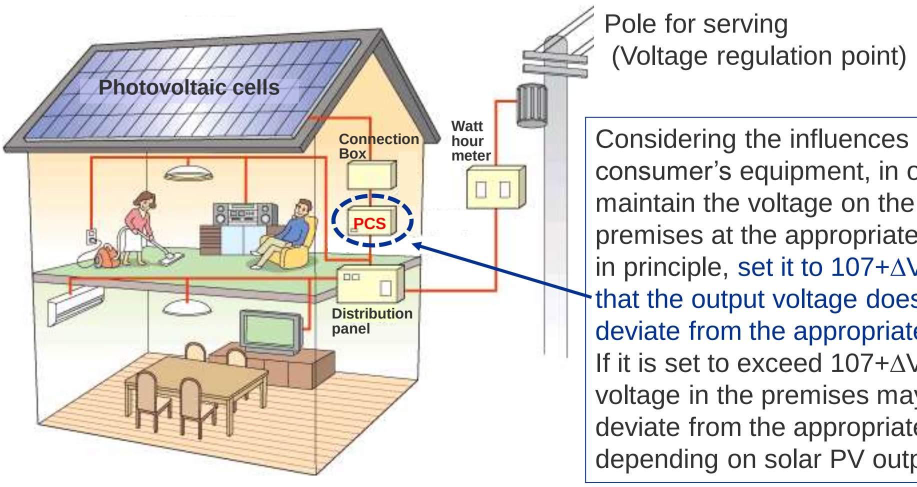
Pole where service wires are connected to a distribution grid.
(Voltage regulation point)

Considering the influences on consumer's equipment on the premises, it is desirable to maintain the voltage on the premises as well. Therefore, the pole for serving is set as the voltage regulation point in principle.
(maintaining at 107V or less*).

* LV regulation: 101±6 V

Consideration of Voltage Fluctuation on Application

Set Value of AVR in PCS

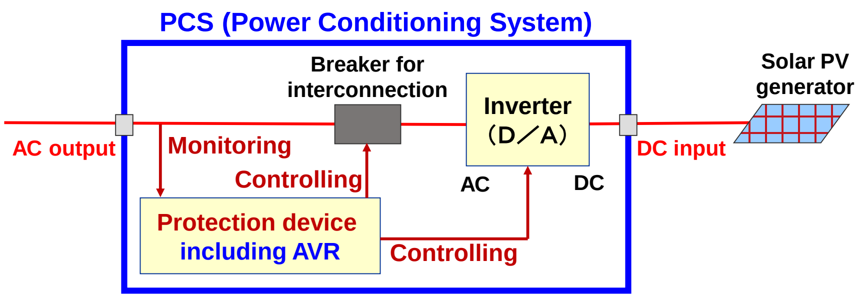


Considering the influences on consumer's equipment, in order to maintain the voltage on the premises at the appropriate voltage, in principle, set it to 107+ΔV(V) so that the output voltage does not deviate from the appropriate range. If it is set to exceed 107+ΔV(V), the voltage in the premises may deviate from the appropriate range depending on solar PV output.

Consideration of Voltage Fluctuation on Application

Function of AVR (Automatic Voltage Regulator)

AVR in a PCS works to secure safety by suppressing power sales (output) so that the output voltage does not deviate from the appropriate range, in order to maintain the customer's equipment at the appropriate voltage in consideration of the influence on the premises load equipment.



All of the PCS certified by JET (Japan Electrical Safety and Environment Technology Laboratories) has this AVR function.

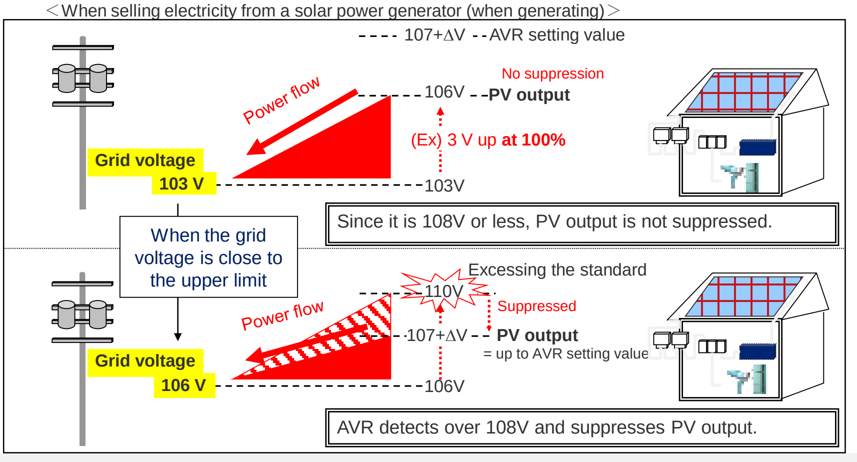
Voltage Rise Suppression of Solar PV Generator

Basically, measures against voltage rise are considered for each individual interconnection, but the form of installing an AVR is standardized in advance due to the need to shorten the individual consultation period and reduce costs.

What is AVR(automatic voltage regulator)?

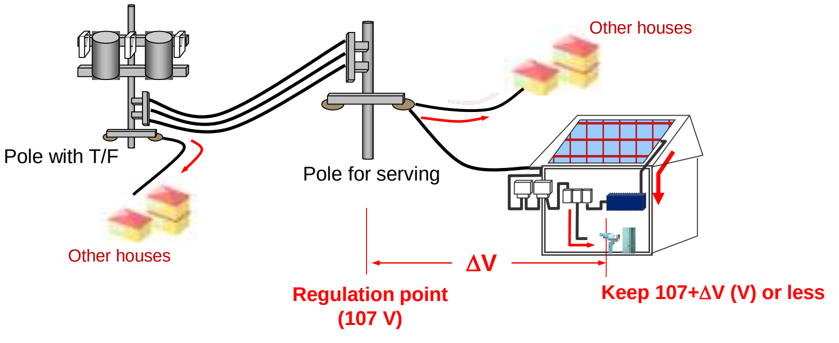
Safety device to suppress the sale of electricity so that the output voltage does not deviate from the appropriate range.

＜When selling electricity from a solar power generator (when generating)＞



Consideration of AVR set value

Voltage regulation point shall be at a pole for serving, and the supply voltage to other consumers shall not deviate from the appropriate voltage range.



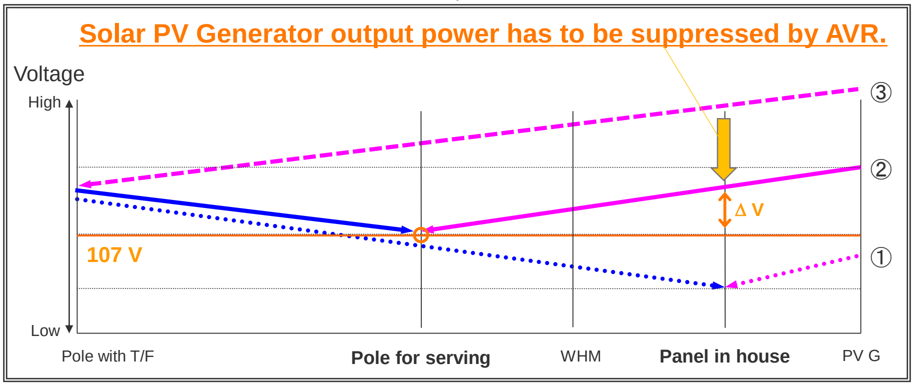
The maximum voltage rise value (ΔV) between an AVR and a pole for serving is calculated and 107V is added to the ΔV to calculate the upper limit of the AVR set value, since it is practically difficult to detect the voltage at the pole for serving and adjust the voltage.

Inquiry for Output Suppression of Solar PV Generator

< Due to voltage rise by solar PV power generator itself >

Example: Case of reverse power flow from solar PV power generator

① PV current < Consumer load current
② Consumer load current < PV current < Total current at service pole
③Total current at service pole < PV current < Total bank current

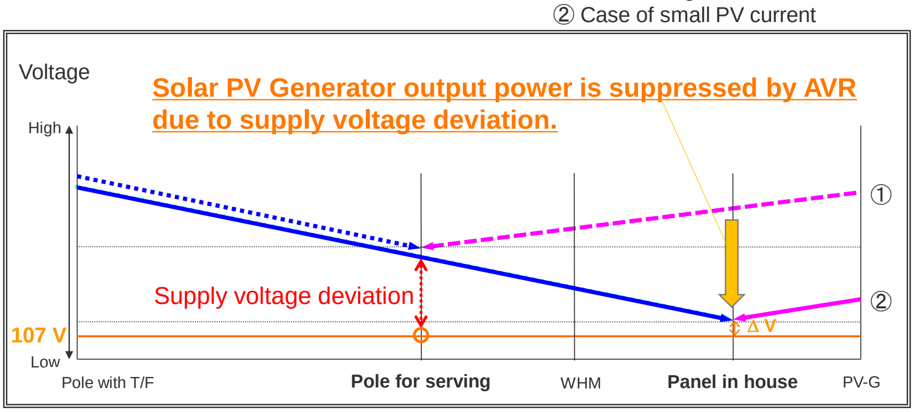


Inquiry for Output Suppression of Solar PV Generator

< Supply voltage deviation from the standard upper limit >

Example: Case of insufficient voltage management such as voltage tap error, Ferranti phenomenon

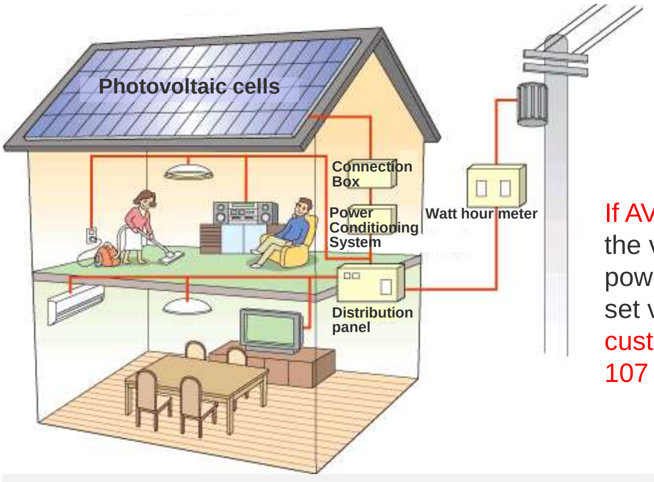
① Case of large PV current
② Case of small PV current



Adjustment of AVR Set Value

< Conditions to change AVR set value >

Under the condition of understanding that a utility is not responsible for any failures of electrical equipment due to voltage rise.



If AVR value is set to 107+ΔV [V], the voltage generated by the PV power equipment may rise to the set value, and the voltage on the customer's premises may exceed 107 V.

Problems

by VRE Interconnected in LV Network

and

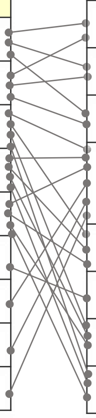
Comparison of Their Countermeasures

Problems in Distribution Networks and Their Countermeasures

Problems by mass VRE	Their countermeasures
• Reverse overflow (high loss)	➢ Shift peak load
• Overflow (high loss) by peak load	➢ Suppress reverse flow
• Voltage range excess (long-cycle)	➢ Keep voltage in a proper range
• Voltage rise around mass VRE	➢ Suppress voltage rise
• Voltage drop in a remote area	➢ Suppress voltage drop
• Phase voltage unbalance	➢ Balance phase voltage
• Voltage fluctuation	➢ Improve fluctuation
• Short-cycle fluctuation	➢ Level voltage to a target value
• Flicker, etc.	➢ Smooth flicker
• Harmonics	➢ Reduce harmonics

Countermeasures by BESS and Other Ways in LV Line

Expectation by BESS in 400V
Shift peak load
Suppress reverse flow
Level voltage to a target value
Suppress voltage rise
Suppress voltage drop
Balance phase voltage
Smooth short cycle fluctuation
Smooth flicker
Reduce harmonics

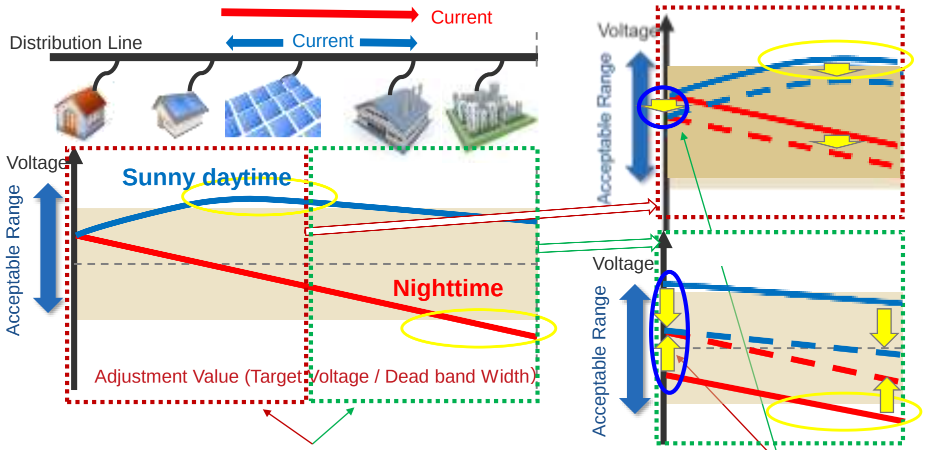


Other countermeasures
Enlarge capacities of MV/LV T/F, LV line, etc.
Add T/F and divide(shorten) line
Adjust demand (tariff, regulations etc.)*
Manage/regulate the setting of VRE output (power factor, harmonics, max. voltage, etc.)*
Manage/revise manual tap of T/F*
Change connection phase of load/VRE*
Install MAI Pole
Install L-SVR

* Countermeasures such as management require no or few investment cost.

[Reference] Countermeasures by Facility Enhancement
- Division of LV or MV line with additional T/F -

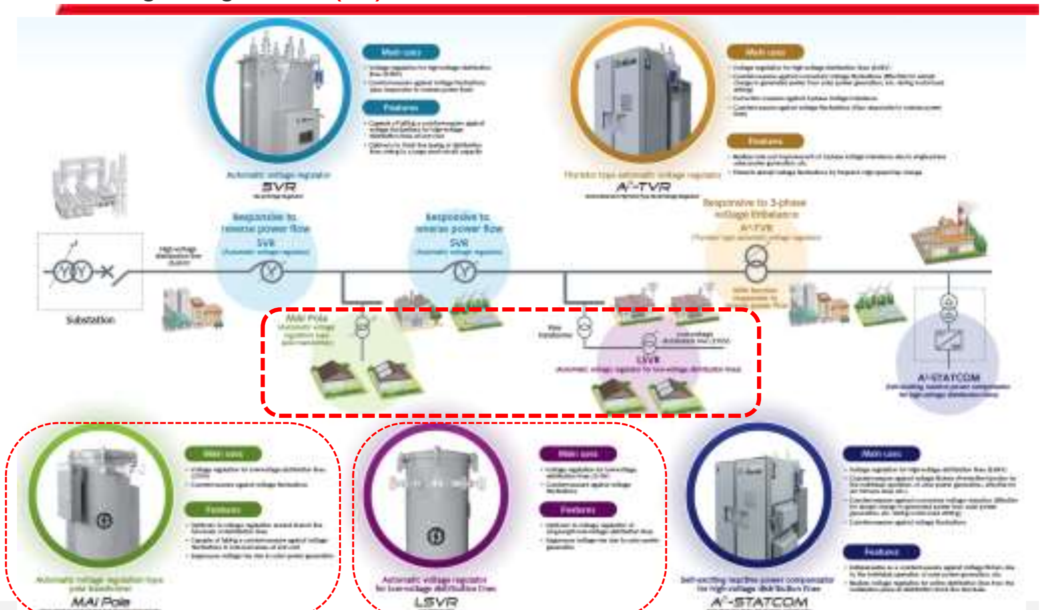
Problems of Voltage range excess | **Countermeasures**



Dividing (shortening) an area supplied by a T/F and shortening LV line ⇒ Adjusting the supplying voltage by tap changer, if needed.

Shortening LV lines also contributes to reduce distribution loss a lot.

[Reference] Countermeasures by Another Facility
- Voltage Regulators (LV) for Countermeasures -



Source: http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

[Reference] Countermeasures by Facility Enhancement - Replacement to Thicker Conductor -

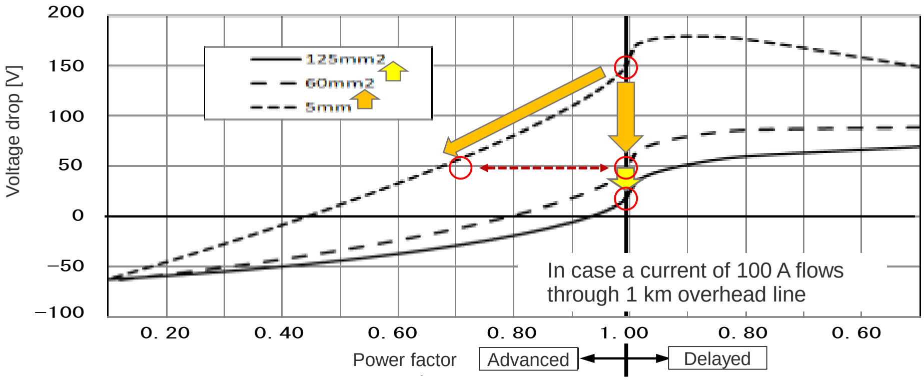
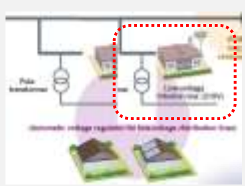


Figure: Conductor thickness and power factor dependency of voltage drop

Voltage drop can be less according to the thicker conductor change from 5 mm to 60 mm² and from 60 mm² to 125 mm² even without power factor change in these conditions.

Ex1) Countermeasures against Voltage Drop Excess **in LV Line in Japan**

Japan	BESS	Additional T/F (LV area division)	LV-SVR
Main spec.	400 V **50 kW – 0.5 hour**	6600/210 V **90 kVA**	210 V **90 kVA**
Material Cost* [$]	0.2 MIL	0.02 MIL	0.02 MIL
Image			

* Costs are roughly estimated in an example case of Japan. Construction costs are not included.

If an additional MV/LV transformer or an LV-SVR would be installed to improve voltage drop excess, it would cost lower than BESS installation.

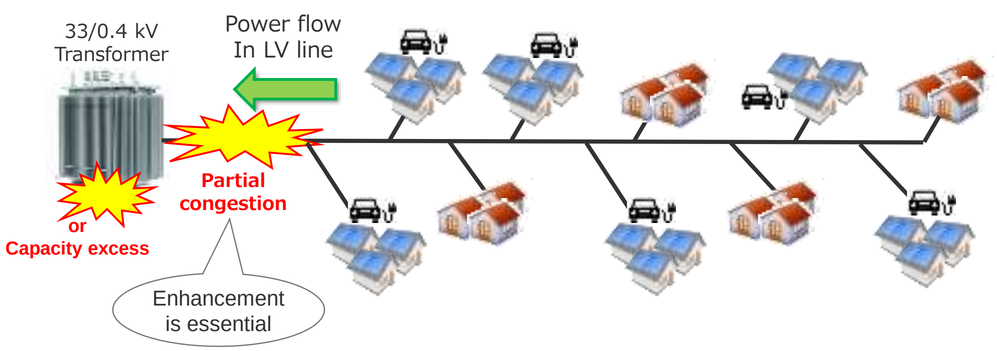
Ex2) Countermeasures against **Voltage Drop Excess** in LV Line in Sri Lanka

Please input the conditions, total and breakdown(if possible) costs, etc. of each countermeasure against voltage drop excess in an example LV case in Sri Lanka.

Sri Lanka	BESS	Additional T/F (LV area division)	Thickening wire (Double capacity wire)
Main spec.	400 V Ex) 50 kW – 0.5 hour	400 V 50 kVA	400 V ?A -> ?A
Total Cost* [$]	? MIL	? MIL	? MIL
Conditions, breakdown, etc. in Sri Lanka			

* Costs would be roughly estimated in an example case of Sri Lanka.

Ex3) **Reverse Flow Excess** in LV Line



How to take a measure?

① Upgrade of the distribution facility to accommodate large amount of VRE
(Facility countermeasure by thickening feeder or transformer division, etc.)

② Install BESS

How much hours needed for?

Ex3) Countermeasures against **Reverse flow excess / Overflow** in LV Line in Sri Lanka

Please input the conditions, total and breakdown(if possible) costs, etc. of each countermeasure against voltage drop excess in an example LV case in Sri Lanka.

Sri Lanka	BESS	Additional T/F (LV area division)	Thickening wire (Double capacity wire)
Main spec.	400 V 50 kW – 2 hours	400 V 50 kVA	400 V ?A -> ?A
Total Cost* [$]	? MIL	? MIL	? MIL
Conditions, breakdown, etc. in Sri Lanka			

* Costs are roughly estimated in an example case of Sri Lanka.

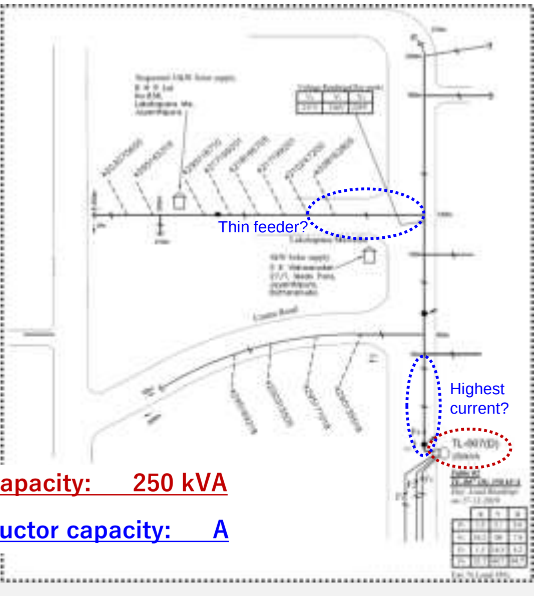
Capacity excess by VRE in LV feeders

- Reverse overflow (high loss) Yes we have
- Overflow (high loss) by peak load Yes we have

How much capacity of SPP are there in the LV feeder?

Table: SPP list in the left figure

Account no	Capacity kW	Connected Phase	Proposed Phase
4218146705	4.2	B	B
4217199201	03	R	R
4208162805	05	B	Y
4295145319	04	R	R
4203070600	04	R	B
4295139918	4.2	B	B
4295171018	03	R	R
4295135216	05	B	Y
4299104900	04	R	R



Total SPP capacity: kVA >? T/F capacity: 250 kVA

Partial SPP current: A >? Conductor capacity: A

*Tentatively supposed to ignore the changeable consumer demand.

Capacity excess by VRE in LV feeders

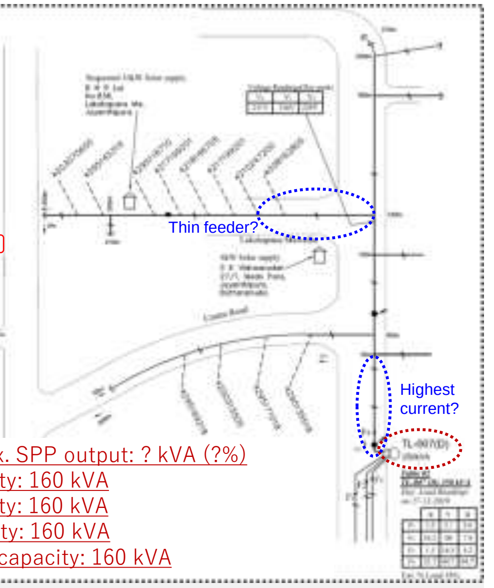
- Reverse overflow (high loss) Yes we have
- Overflow (high loss) by peak load Yes we have

How much capacity of SPP are there in the LV feeder?

Table: List of 11/0.4 kV T/F and installed SPP capacity

CSC	TRANSFORMER CODE	Number of Accounts	Inverter	Panel Capacity	Transformer Capacity	Type	
01	AZ0184	43	252	236	250	D	95%
01	AZ0197	20	136	133	160	D	83%
01	AZ0204	31	214	197	250	D	79%
01	AZ0206	24	133	129	160	D	80%
01	AZ0208	16	124	122	160	D	76%
01	AZ0223	18	150	135	160	D	84%
01	AZ0228	33	218	203	250	D	81%
01	AZ0512	26	191	167	160	D	104%
01	AZ0518	14	98	87	100	D	87%
01	AZ1028	14	79	79	100	D	79%
03	AZ8136	1	800	886	1,000	C	89%
03	AZ8176	1	200	211	250	C	84%
03	AZ8190	1	120	126	160	C	79%
06	AZ0444	13	153	128	160	D	80%
06	AZ0823	13	90	88	100	D	88%
06	AZ0830	8	76	76	100	D	76%
06	AZ8510	1	225	243	250	C	97%
06	AZ8524	1	120	132	160	C	83%

* Some of the data might not be updated.



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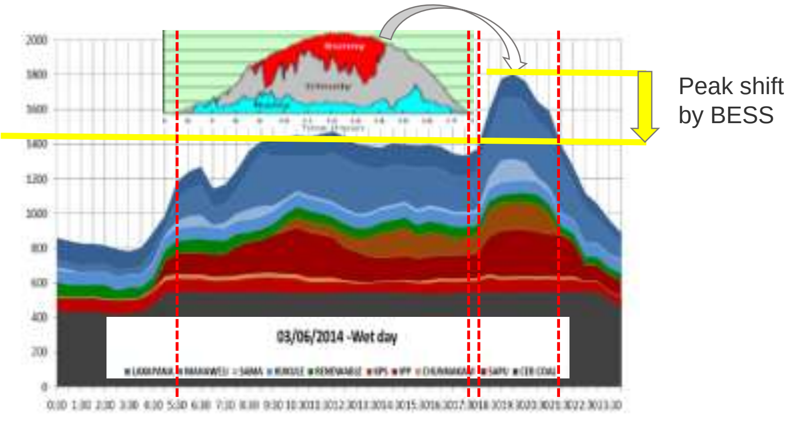
"SPP output >? Load demand" at the same moment.

Total SPP capacity: 167 kVA > Actual max. SPP output: ? kVA (?%)
Actual max. SPP: 167 x ?% kVA > T/F capacity: 160 kVA
Maximum demand: kVA >? T/F capacity: 160 kVA
Minimum demand: kVA >? T/F capacity: 160 kVA
(Actual Max. SPP) – (Min. demand)= ? kVA >? T/F capacity: 160 kVA

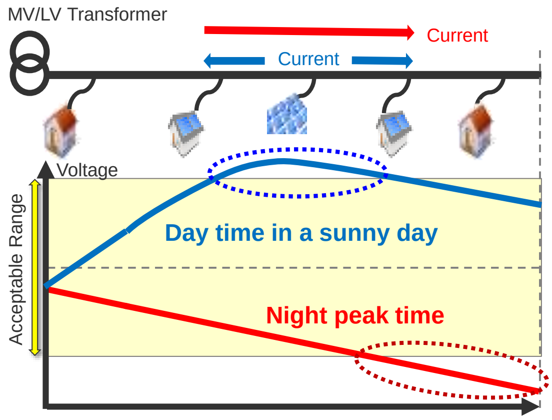
Capacity excess by VRE in LV feeders - Consideration of Peak Shift Hours -

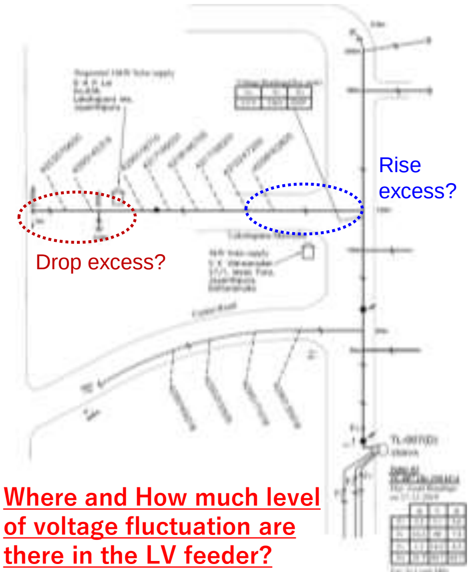
Shift peak load by BESS only during limited peak time
Or enhance whole facility capacity in LV network



Voltage Range Excess by VRE in LV feeders

- Voltage range excess (long-cycle)
  - Voltage rise around mass VRE — Yes we have
  - Voltage drop in a remote area — Yes we have
  - Phase voltage unbalance — Yes we have





Where and How much level of voltage fluctuation are there in the LV feeder?

Problems

by VRE Interconnected in MV Network

and

Comparison of Their Countermeasures

Countermeasures by BESS and Other Ways in MV Line

CHUBU Electric Power / NIPPON KOEI

First of all, consider who are responsible for countermeasures.

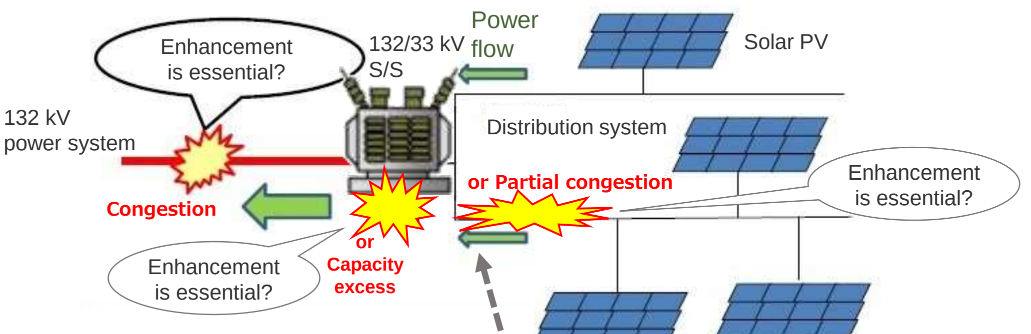
Expectation of BESS in MV
Capacity overload by peak load
Capacity overload by reverse flow
Level voltage to a target value
Suppress voltage rise
Suppress voltage drop
Balance phase voltage
Smooth short cycle fluctuation
Smooth flicker
Reduce harmonics

Other countermeasures
Enlarge capacities of T/F at S/S, MV line, etc. Add T/F with space and MV line (new feeder)
Adjust demand (tariff, regulations etc.)**
Manage/regulate the settings of VRE output (power factor, harmonics, max. voltage, etc.)**
Manage/control automatic tap changer of LRT**
Change connection phase of 1phase load**
Install SVR (long cycle) **[6kV-5000kVA, 0.1MIL$]***
Install TVR (short cycle) **[6kV-5000kVA, 0.15MIL$]***
Install STATCOM (20ms~) **[6kV-300kVar, 0.15MIL$]***

* Costs are roughly estimated in some example cases in Japan.
** Countermeasures such as control and management require no or few investment cost.

[Reference] Countermeasures against Mass VRE Installation Problems - Enhancing Facility or Installation of BESS -

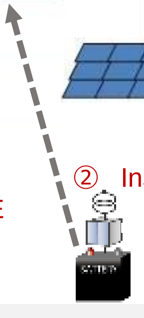
CHUBU Electric Power / NIPPON KOEI



How to take a measure?

① Upgrade of the facility to accommodate large amount of VRE (Facility Countermeasure by thickening transmission line)

② Install BESS



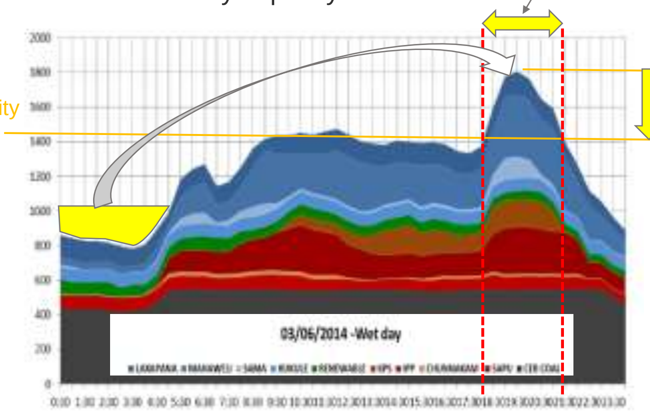
How long needed?

[Reference] Capacity excess by VRE in MV feeders
- Enhancing Facility or Installation of BESS -

CHUBU Electric Power
NIPPON KOEI

Shift peak load by BESS only during **limited peak time**
or enhance whole facility capacity in LV network

Suppose capacity limit here.



Peak shift by BESS

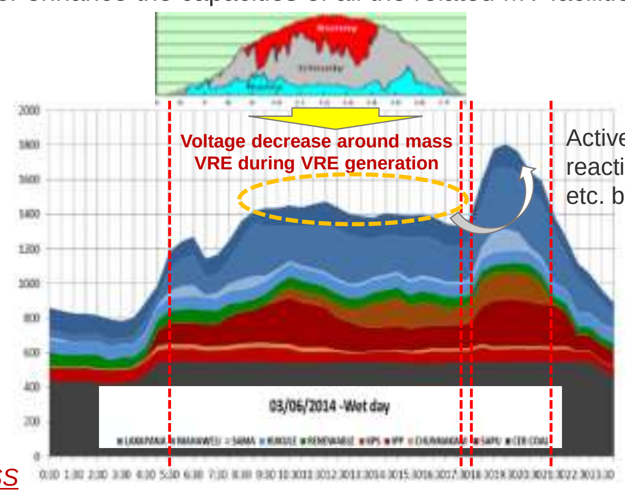
Merit of BESS

Facility enhancement costs the same between longer and shorter compensation, while BESS introduction costs lower in case of shorter compensation.

[Reference] Voltage Rise Excess by VRE in MV feeders
- Enhancing Facility or Installation of BESS -

CHUBU Electric Power
NIPPON KOEI

Suppress voltage risen by VRE output in sunny daytime, by absorbing (charging) BESS, etc. or enhance the capacities of all the related MV facilities

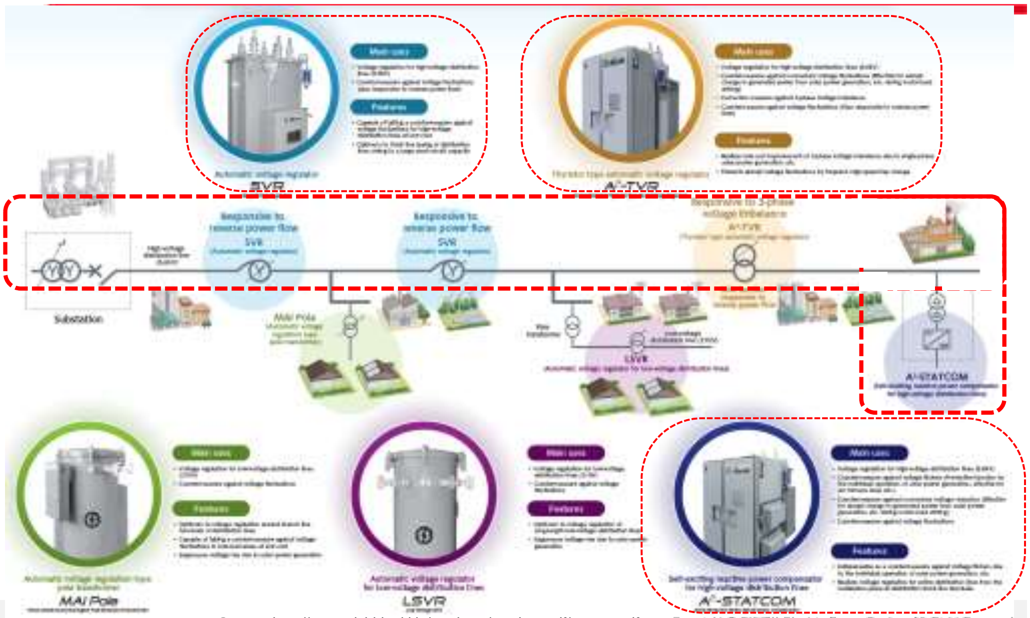


Active power shift, reactive power output, etc. by BESS

Merit of BESS

BESS has multi-functions to control output power/voltage.

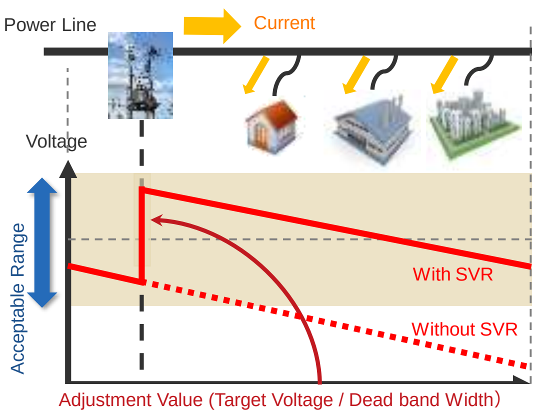
[Reference] Voltage Regulators (MV) for Countermeasures



48 Source: http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

[Reference] Countermeasures against Voltage Drop by Another Facility - Installation of SVR -

- Step Voltage Regulator(SVR) is used for distribution voltage management, which compensates voltage by switching tap automatically.
- SVR monitors system voltage, and if the voltage deviation happens, SVR changes the tap to keep the voltage in a suitable range.



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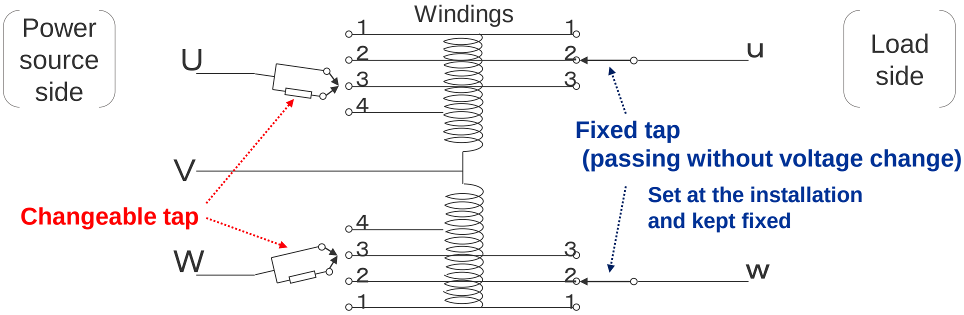
SVR (Step Voltage Regulator)

Rated voltage: 6.6, 11 and 22 kV

Tap Change Structure of 6.6 kV V-Connection SVR



Fixed tap	Changeable tap	Output voltage	Winding ratio (primary/secondary)
2	1	One step down: -150V	6750/6600
	2	No step up/down: 0V	6600/6600 (No step)
	3	One step up: 150V	6450/6600
	4	Two steps up: +300V	6300/6600

Reference: Outline of advanced SVR

- ●タップ間電圧を細分化（150⇨75V）し，不感帯幅も縮小（±1.5%⇨0.8%）することで，電圧調整能力が高い
- ●30分単位に目標電圧ならびに不感帯幅を遠隔で設定することができるため，PVが大量に連系する配電線など時間帯によって潮流が大きく変動する場合にも，高圧配電線の電圧を上・下限値内に収めることが可能
- ●67リレーを具備せず，逆送時に逆送用整定値と変電所方向の判定機能により電圧を調整することもできるため，故障時などの系統切替後においても電圧調整が可能

SVR2G 外観

＊　開発中

H柱を基本とするものの，用地事情や配電設備（支持物強度計算）の条件を満足した場合は単柱装柱も可能

≪機器定格≫

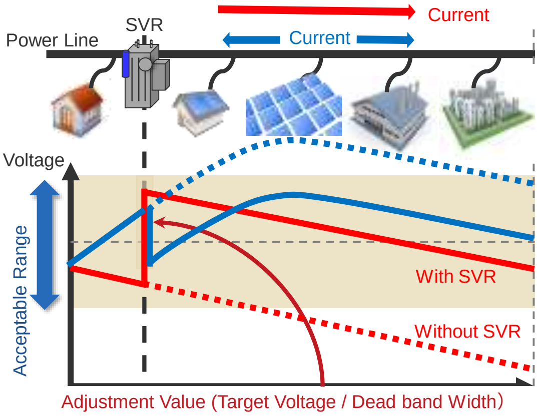
項目	現行SVR	SVR2G
一次タップ電圧	7,050 ～6,300V	6,975 ～6,375V
タップ間電圧	150V	75V
タップ点数 (素通し含む)	6	9
電圧調整範囲	+450 ～－300V (2段)	① 375 ～－225V ② 300 ～－300V
素通しタップ番号	3	① 4　　② 5

≪継電器仕様≫

項目	現行SVR	SVR2G
電圧調整相	単相	三相平均
基準電圧整定範囲	95.0～119.5V(0.5Vステップ)	95.0～119.5V(0.1Vステップ)
不感帯整定範囲	±1.0～4.0%(連続整定)	±0.8～4.0%(0.1%ステップ)
動作時限整定範囲	45－60－90－120－150－180sec (定限時型)	15～180sec (定限時型 / 1secステップ)
LDC	R, X ：0～24%（1%ステップ）	同左

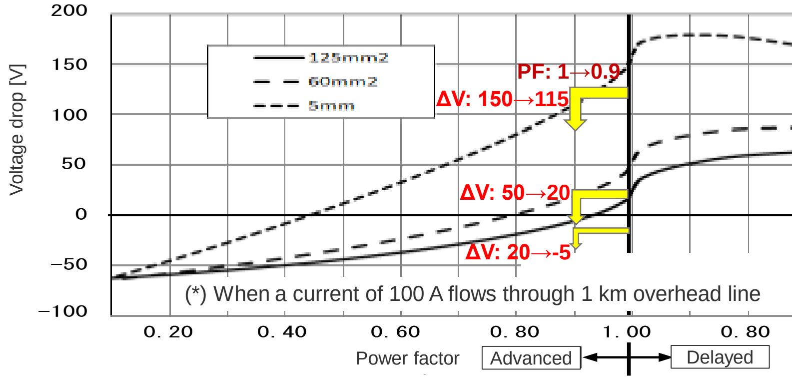
Outline of SVR for Distribution Voltage Management

- ■ Step Voltage Regulator(SVR) is used for distribution voltage management, which compensates voltage by switching tap automatically.
- ■ SVR monitors system voltage, and if the voltage deviation happens, SVR changes the tap to keep the voltage in a suitable range.



[Reference] Countermeasures against Voltage Drop by Another Facility - Installation of SVC (Statcom) -

[Occurrence of the Ferranti phenomenon]



(Example) Change in voltage drop due to power factor change

·As power factor advances, the voltage drop turns to voltage rise.

·Ferranti phenomenon tends to occur in case of thicker conductor.

Ex) Countermeasures against Voltage Drop Excess in MV Line

Japan	BESS	Additional T/F	SVR
Main spec.	33 kV 1 MW – 3 hours	77/6.6 kV 10 MVA	6.6 kV 5000 kVA
Material Cost* [$]	4 MIL	Several MIL (1 MIL for T/F)	0.1 MIL
Image			

* Costs are roughly estimated in an example case of Japan. Construction costs are not included.

Even though the SVR cost of the same scale would be several times higher, the SVR cost would be lower than BESS cost. (Usually, the necessary SVR capacity is less than GSS T/F capacity, as the SVR is installed on the way of MV feeder.)

It is difficult to compare the installation costs between BESS and an additional HV/MV transformer with some HV/LV lines extension, as the better one would depend on case by case.

However, if active power as well as voltage countermeasures would be necessary due to a case of reverse power flow, etc. BESS would be more effective than other countermeasures.

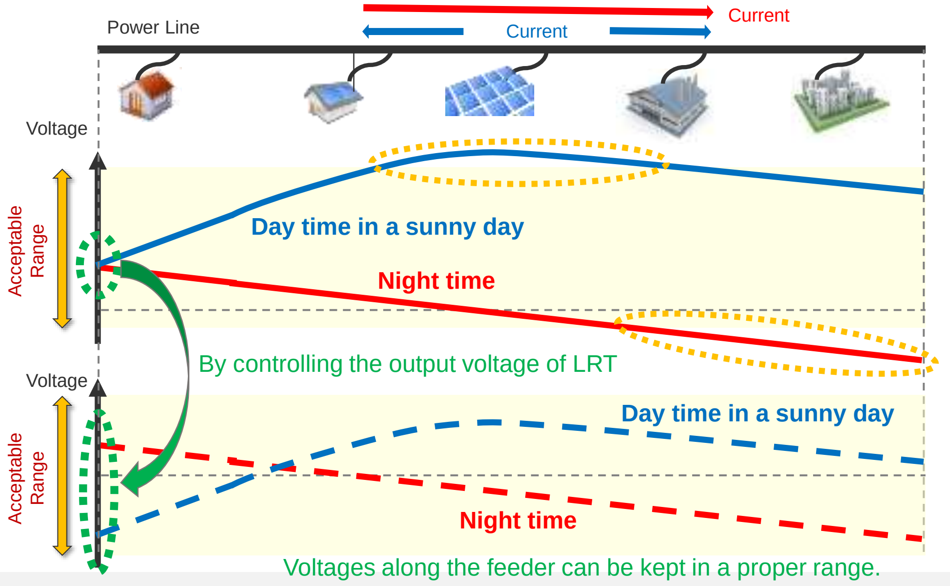
Ex) Countermeasures against Voltage Drop Excess in MV Line

Sri Lanka	BESS	Additional T/F and T/L extension	Thickening T/L(transmission line)
Main spec.	33 kV 1 MW – 3 hours	132/33 kV ? MVA	33 kV ?A (? kVA)
Material Cost* [$]	? MIL	? MIL (? MIL for T/F)	? MIL
Conditions, breakdown, etc. in Sri Lanka			

*Please estimate in an example case of Sri Lanka.

Please estimate the example costs of an additional HV/MV transformer with some HV/LV lines extension and thickening transmission line, though the better one would depend on each case.

[Reference] Countermeasures against Voltage Drop - Control and Management of Facility (LRT) -



Voltages along the feeder can be kept in a proper range.

[Reference] Countermeasures against Voltage Drop
- Methods of setting target voltage of LRT at GSS -

【Example】 In case of Substation Bank ”D1B” at 10:00

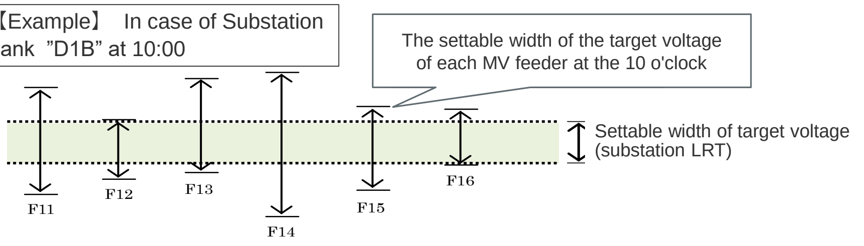


Figure Calculation diagram of settable width (distribution line) of target voltage

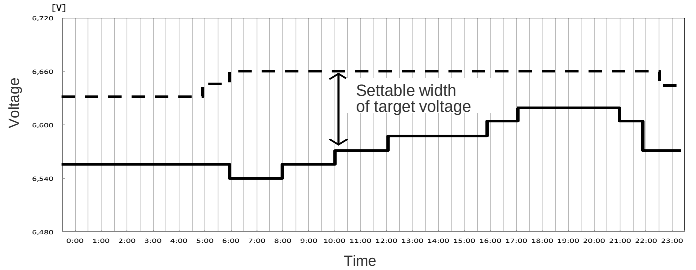
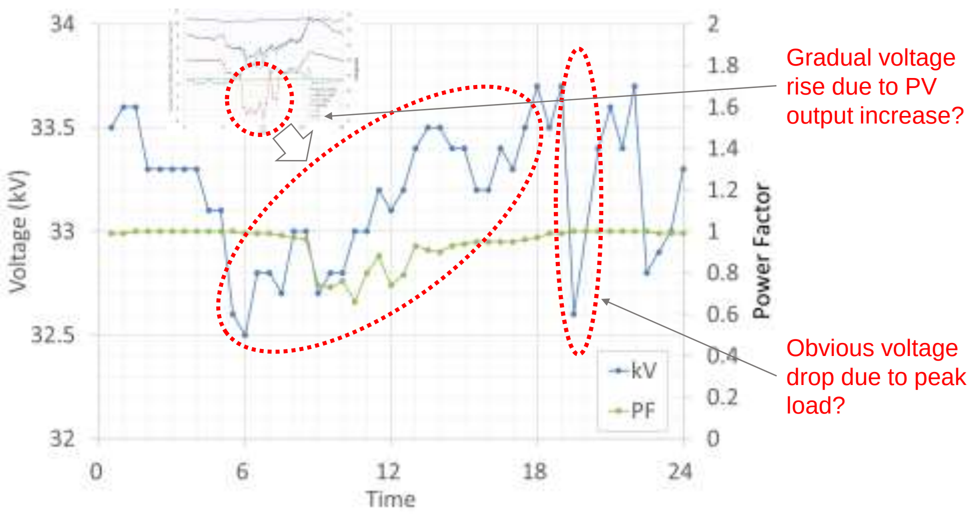


Figure Image of settable width of target voltage for each time zone (substation LRT)

[Reference] Countermeasures against Voltage Fluctuation in Valachchenai F5
- Scheduled Control and Management of LRT -



The voltage drop might be eased to a certain extent without countermeasure facility, by managing and controlling output voltage with LRT at the GSS.

Candidate Countermeasures against Power/Voltage Fluctuation in MV or LV Lines

Regulations in Sri Lanka against Power/Voltage Fluctuations

■ Allowable Voltage range

- 33/36 kV
- 11/12 kV
- 230/400 V

Classification	Normal	Contingency
33/36 kV	-6% ~ +6%	-10% ~ +10%
11/12 kV	-6% ~ +6%	-10% ~ +10%
230/400 V	-6% ~ +6%	-10% ~ +10%

■ Harmonics

- Total
- Each

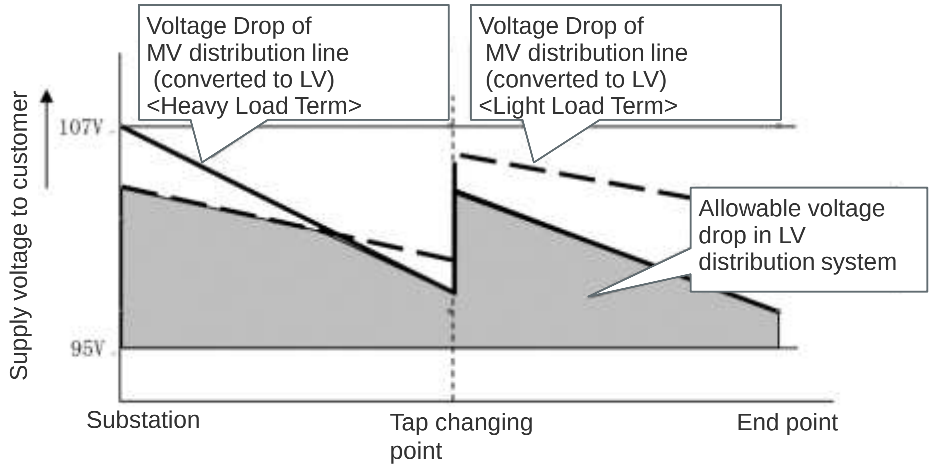
(Reference in Japan)
When installing the inverse converter (inverter), set the harmonic outflow current to the followings.
・Total current distortion: 5% or less
・Each current distortion: 3% or less

■ Other Related Regulations in Sri Lanka

- ???
- ???
- (Please confirm **by each DD and LECO**, and share next time)

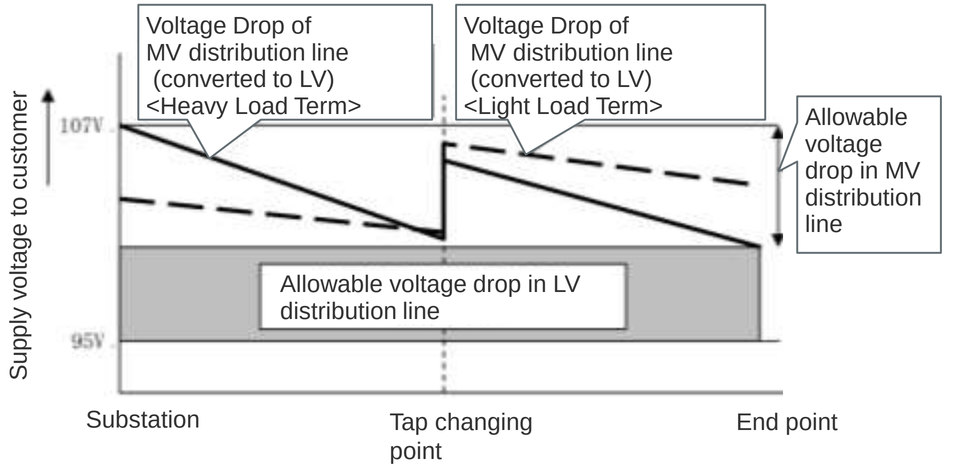
Voltage Regulation Method in MV and LV Distribution Lines

Method for separately managing the MV distribution line and the LV distribution line separately. (separate regulation)



Voltage Regulation Method in MV and LV Distribution Lines

Method for regulating the voltage drop of the MV distribution line and the LV distribution line together (Integrated regulation)



Voltage Regulation Method in MV and LV Distribution Lines

Voltage regulation of the distribution line can be thought of as

(Integrated regulation method) for regulating voltage drop of the MV distribution line and the LV distribution line together

(Separated regulation method) for separately managing the MV distribution line and the LV distribution line separately.

The voltage drop of the low-voltage system is not related to the voltage drop of the medium-voltage system

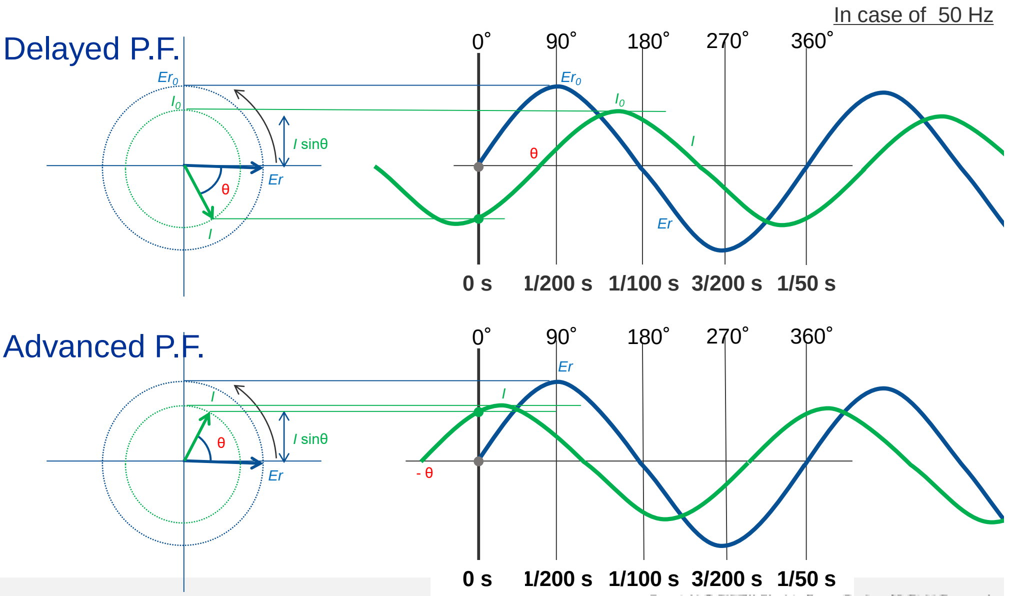
In order to improve the efficiency of regulation and to easily correspond to changes in the system of MV distribution lines, voltage regulation is generally performed by the integrated regulation method.

Suppression of Advanced Power Factor

Power factor has different characteristics in each distribution line, and fluctuates according to the load current. There is almost no distribution line with constant power factor.

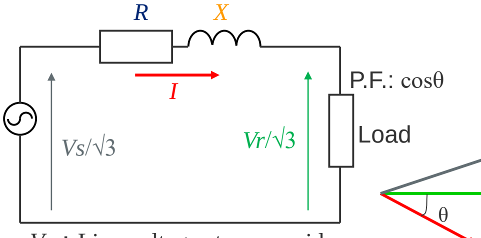
When power factor deteriorates on advanced side, voltage rises. (Ferranti effect)

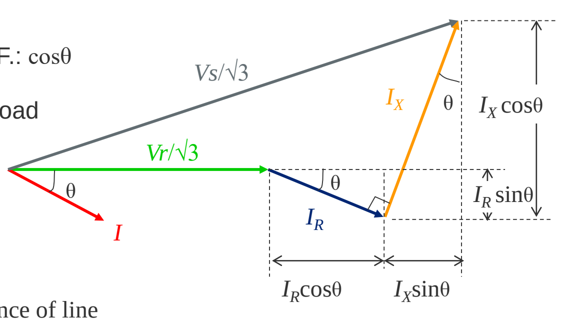
(Ref.) Lagging/Leading Power Factor



(Ref.) Calculation Formula for Voltage Drop (1)

- Three-phase three-wire balanced -





Vs : Line voltage at source side
Vr : Line voltage at load side
I : Current of line
R : Resistance of line, X : Reactance of line

$$Vs/\sqrt{3} = \sqrt{\left(Vr/\sqrt{3} + I \cdot R \cdot \cos\theta + I \cdot X \cdot \sin\theta\right)^2 + \left(I \cdot X \cdot \cos\theta - I \cdot R \cdot \sin\theta\right)^2}$$

Hence, the first term >>the second term,
generally

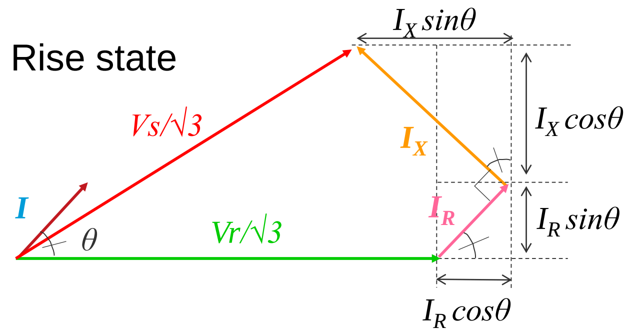
$$Vs/\sqrt{3} = \sqrt{\left(Vr/\sqrt{3} + I \cdot R \cdot \cos\theta + I \cdot X \cdot \sin\theta\right)^2}$$

$$V_{drop} = Vs - Vr \approx \sqrt{3}\, I\, (R\cos\theta + X\sin\theta)$$

(Ref.) Calculation Formula for Voltage Drop (2)

- Three-phase three-wire balanced -

Vr > Vs: Voltage Rise state



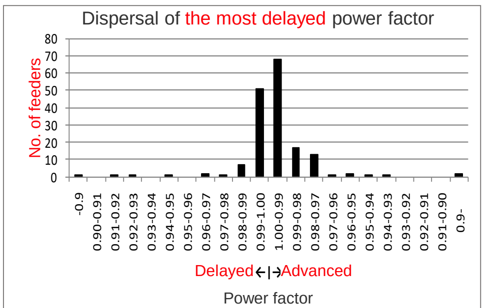
$$V_{drop} = Vs - Vr \approx \sqrt{3}\, I\, (R\cos\theta - X\sin\theta)$$

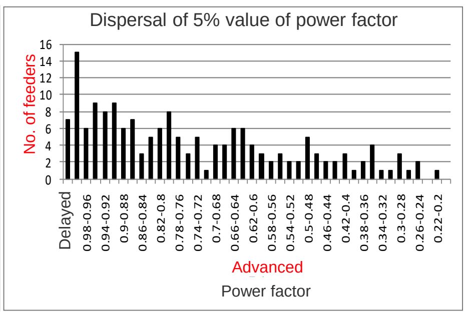
Ferranti Effect

- Load current: Leading current
- Voltage at load side exceeds Voltage at power source side

Suppression of Advanced Power Factor

[Examples of Measured power factor (Variation in feeder)]





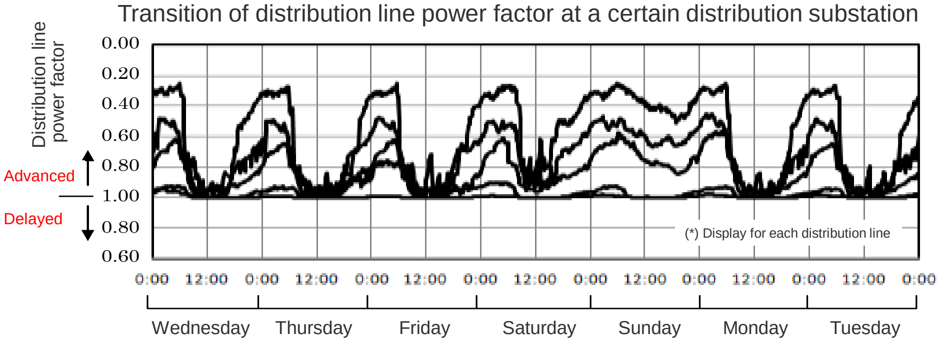
As a result of totaling with "the latest delay", the distribution line power factor is concentrated between 0.99 delay and 0.99 advanced.

When looking at 5% value, there are large variations on the advance side.

Suppression of Advanced Power Factor

[Examples of Measured power factor (Fluctuation in time)]

Transition of distribution line power factor at a certain distribution substation



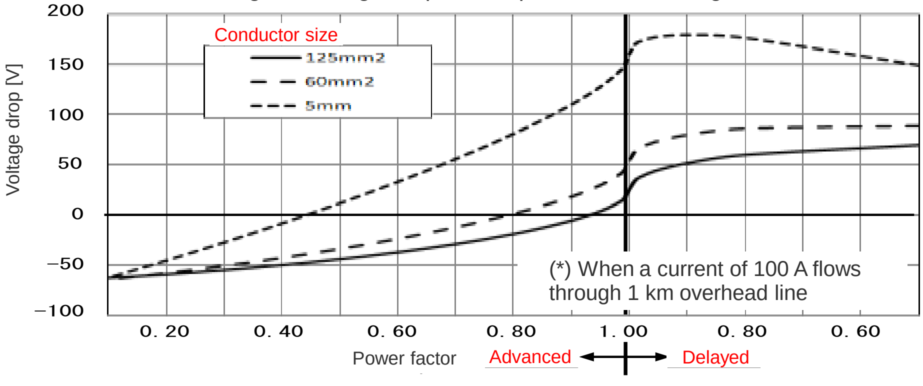
The power factors in distribution lines fluctuate widely, depending on times and days of the week.

The rates of fluctuation are very different for each distribution line.

Suppression of Advanced Power Factor

[Example of occurrence of the Ferranti phenomenon]

Change in voltage drop due to power factor change



As the power factor advances, the voltage drop turns to voltage rise.

Voltage rise tends to occur as a conductor has a larger diameter.

Suppression of Advanced Power Factor

The power factor (delay power factor of 0.95), which was generally assumed In previous time, greatly differs from the actual condition of the distribution line power factor. Setting the target supplying voltage with the power factor higher than the actual condition induces deviation of the upper limit value.
It is necessary to consider a change in voltage drop (voltage rise) due to a change in power factor at the time of determining the target voltage. (Ferranti phenomenon is not a special event)

⇩ Application method of power factor (voltage control)

Reflect the power factor per hour in the voltage drop (increase) calculation. The power factor is assumed from the current-power factor correlation measured in units of distribution lines for a certain period.

Suppression of Advanced Power Factor for LV lines

<Addition of measures against voltage rise (constant power factor control) in low-voltage interconnection>

There is concern that the voltage of the distribution system will rise due to the increase in power generation equipment that is interconnected with reverse power flow in the low-voltage system.

As a concrete measure against this voltage rise, it is stipulated that it is effective to equip the low-voltage power conditioner (low-voltage PCS) with constant power factor control.

On the other hand, interconnection of low-voltage photovoltaic power generation equipment (low-voltage PV) with constant power factor operation, which has been rapidly introduced and expanded in recent years, has not yet become widespread, and in order to spread it, it is a uniform standard nationwide.

It was necessary to determine and regulate the power factor value.

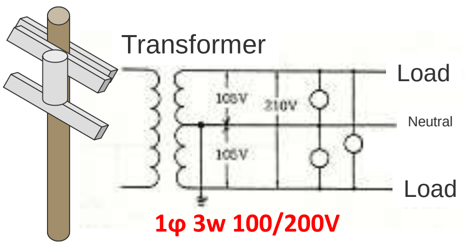
Therefore, this time, it was examined that the power factor value that minimizes the total cost of system countermeasure cost, countermeasure cost due to increase in PCS capacity, and power generation opportunity loss, and standard power factor value (95%) for low-voltage PV has been added to the regulations.

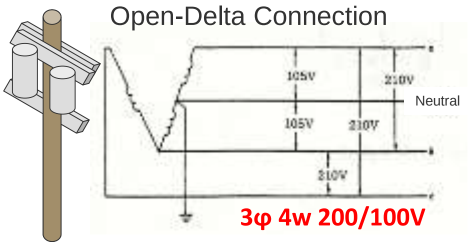
[Grid-interconnection Code, added in 2017]

*LV System with Single-Phase Transformers in Japan

CHUBU Electric Power
NIPPON KOEI

LV Distribution Supply System





Capacity (KVA)
5, 10, 20,30, 50, 75

Single Phase Transformer   Combined Transformer

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Voltage Regulation by Transformer Tap Change

CHUBU Electric Power
NIPPON KOEI

[Tap of pole transformer]

Primary voltage of a pole transformer is determined by JIS C 4304 “6 kV Oil-immersed distribution transformers ”

Single-Phase Transformer

(Secondary voltage)

210/105 V ⇐

(Primary voltage)

- 6,750 V
- 6,600 V
- 6,450 V
- 6,300 V

The role of the pole transformer in regulating the voltage is large.

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Voltage Regulation by Transformer Tap Change

[Tap of pole transformer]

A transformer lid is normally opened on the ground and an inside tap is set to a proper position, before installing it on a pole.

Transformer capacity (kVA)
5, 10, 20,30, 50, 75

In Three-Phase System

For three-phase use, combining two single-phase transformers

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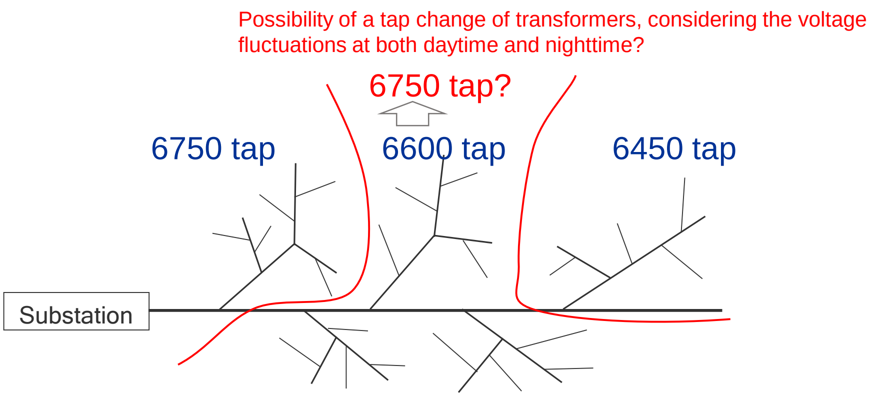
Voltage Regulation by Transformer Tap Change

[Tap of pole transformer]

It is important to properly select a tap of a pole transformer according to the voltage of each section of a MV distribution line.



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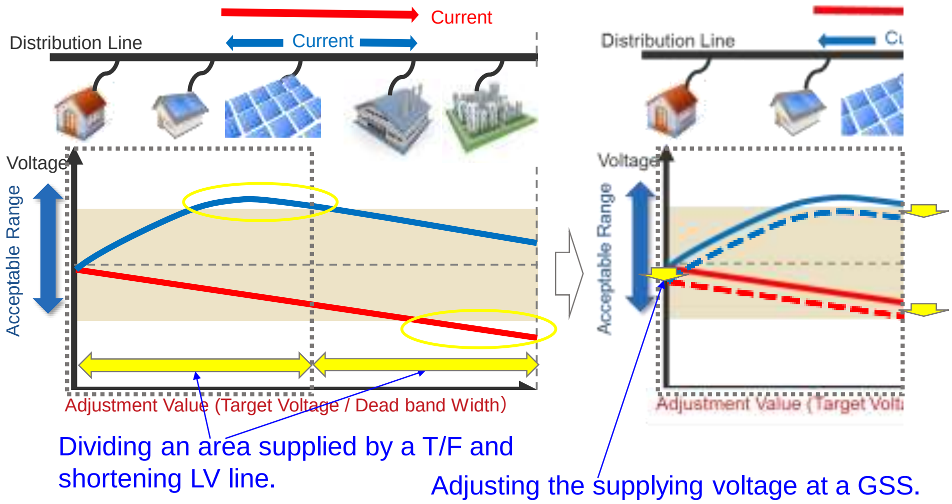
Shortening LV line

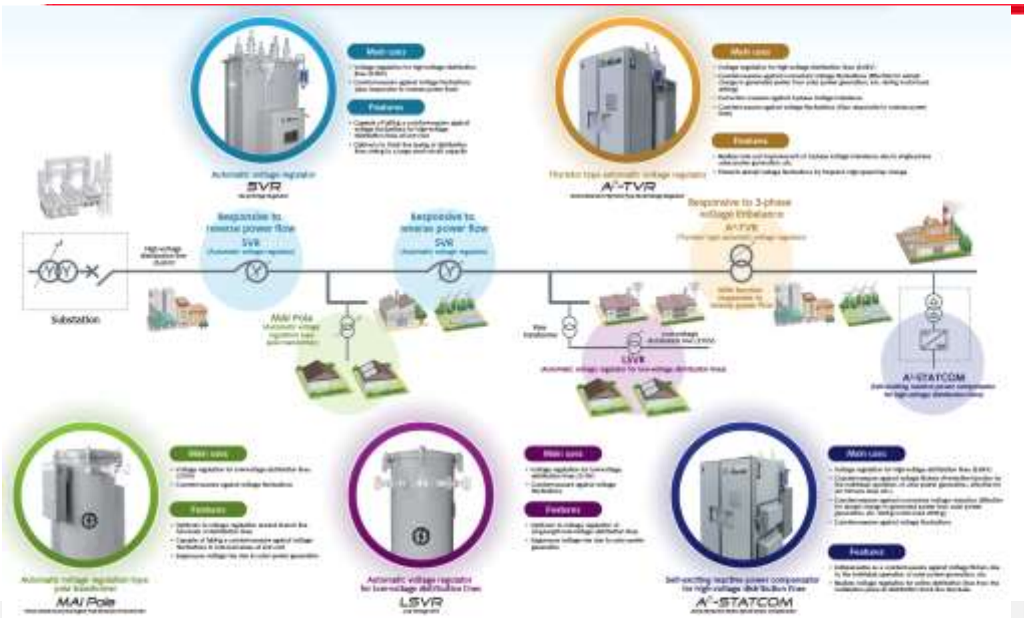


Shortening LV lines also contributes to reduce distribution loss a lot.

Number of Distribution Components Installed in CEPCO

Components	Unit	CEPCO Total	Remarks
Electricity Poles	pieces	2,834,318	
Overhead line (Span length)	km	130,072	
Underground line (Span length)	km	4,621	
Transformers (6.6kV / 100V, 200V)	units	1,597,676	1 Tr / 2 poles 2 Tr / 4 poles
Distribution Substations	units	783	
Distribution line	feeders	8,640	11 feeders / SS
Population	persons	16,000,000	13%
Land area	km^2	39,100	10%
Population density	person / km^2	409	

Variety of Voltage Regulators



80 Source: http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

Variety of Voltage Regulators

Main uses

- Voltage regulation for low-voltage, distribution lines (210V)
- Countermeasure against voltage fluctuations

Features

- Optimum to voltage regulation of long-length low-voltage distribution lines
- Suppresses voltage rise due to solar power generation

81 http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

Variety of Voltage Regulators

LSVR

Low Voltage SVR

Supportive of voltage regulation for low-voltage distribution lines

LSVR has functions to monitor the secondary voltage, and regulate voltage according to voltage fluctuations. Having these functions, LSVR is effective for voltage regulation in areas where low-voltage distribution lines is long, and also for suppression of voltage fluctuations due to solar power generation, etc. Furthermore, in order to take a balance of voltage in single-phase, 3-wire distribution lines, LSVR has a built-in voltage balancer.

Number of phases	1
Rated frequency	60Hz
Rated line capacity	30kVA
Rated secondary voltage	210V – 105V
Voltage regulation width	± 2.5%, ± 5%
Reference voltage	Variable in a range of 100V – 109V
Dead zone	Variable in a range of ± 1.5V – 4.5V
Operating time	Variable in a range of 10Vs – 1000Vs

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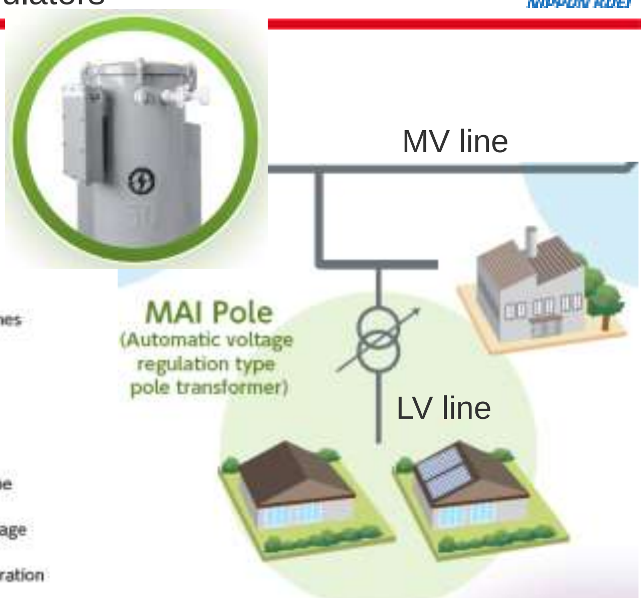
http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

Variety of Voltage Regulators



Main uses

- Voltage regulation for low-voltage distribution lines (210V)
- Countermeasure against voltage fluctuations

Features

- Optimum to voltage regulation around branch line terminals of distribution lines
- Capable of taking a countermeasure against voltage fluctuations in low-load areas at low cost
- Suppresses voltage rise due to solar power generation

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http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

Variety of Voltage Regulators

MAI Pole

Suppresses voltage fluctuations in low-voltage distribution lines due to solar power generation, etc.

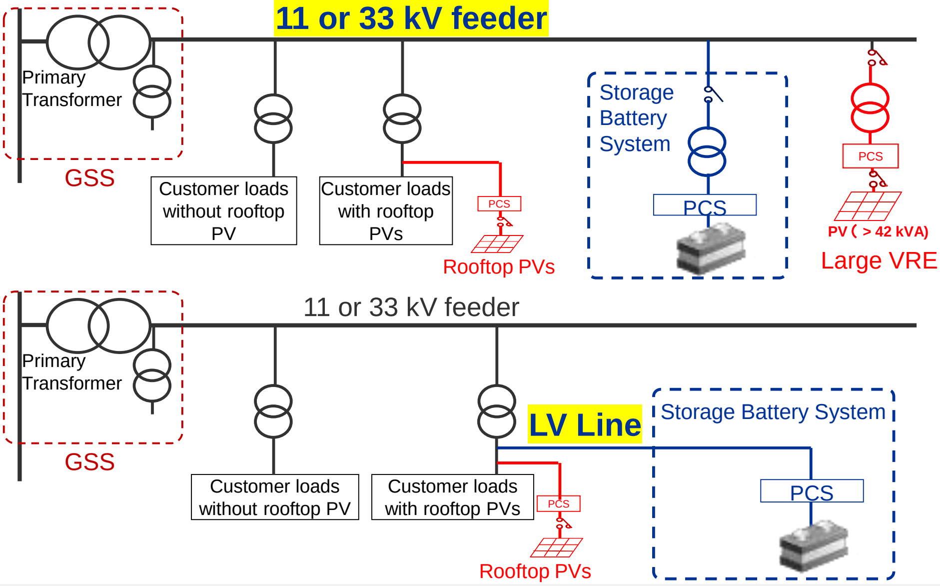
Most-Advanced & Intelligent Pole Mounted Transformer

MAI Pole is a pole transformer with a combination of tap selecting switch and controller and an addition of automatic voltage regulating function. Being capable of properly regulating voltage on the low-voltage side, this transformer can prevent unwanted stop of solar power generation.

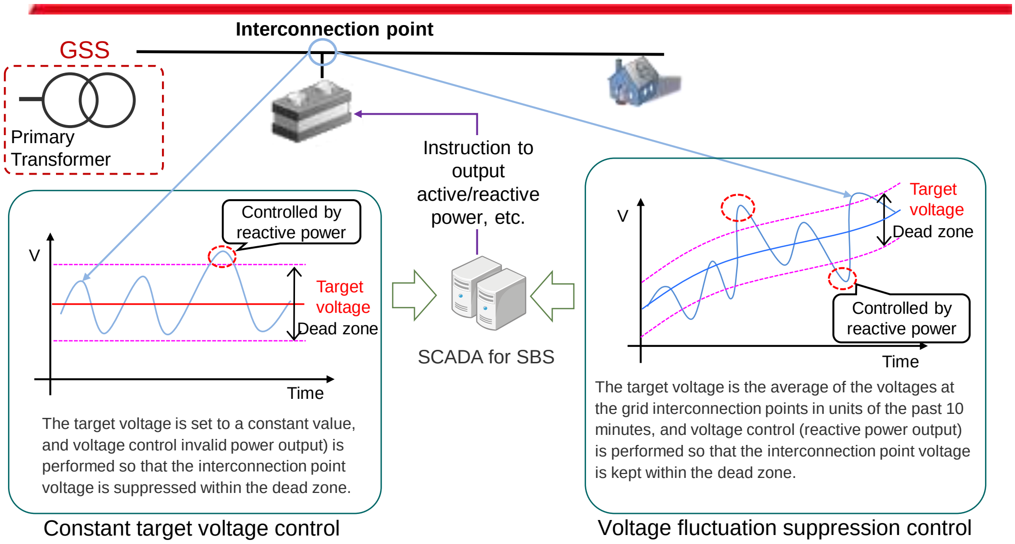
Number of phases	1
Rated frequency	60Hz
Rated primary voltage	6600V
Primary tap voltage	6900V/6750V/6600V/6450V/6300V
Rated secondary voltage	210V – 105V
Rated capacity	10kVA, 20kVA, 30kVA, 50kVA
Reference voltage	Variable in a range of 100V – 109V
Dead zone	Variable in a range of ± 1.5V – 4.5V
Operating time	Variable in a range of 10Vs – 1000Vs

http://www.aichidenki.jp/products/catalog_pdf/svg-tvr.pdf

Countermeasures by Storage Battery System



Countermeasures by Storage Battery System



Constant target voltage control

Voltage fluctuation suppression control

Variety of control methods by SBS such as target voltage control, voltage fluctuation suppression control

Technical Matters on VRE (DER) Interconnection

Technical Matters Required for DER Interconnection

Matters	Potential risk occurred by distributed energy resource connection
Grid protection quality (Supply reliability)	① Inner failure of VRE induces other customer equipment. ② Increase of short-circuit current by VRE induces the excess of that of equipment. ③ Expansion of the accident by continuing to generate power from distributed power sources, in the event of a power system accident. ④ No OCR detection at a PSS induces more serous damage. ⑤ A detection error by OCR in other feeders induces additional power outages.
Safety and Equipment Maintenance	⑥ Only DER keeps power generation to supply to a grid, even after stopping power supply in the grid. ⑦ Asynchronous connection (short-circuit) between a DER and a power grid damages a power facility, when the grid is restored.
Voltage fluctuation	⑧ DER connection to a grid raises voltage fluctuation in a grid.
Harmonics	⑨ Harmonic current flows from a DER to a grid.
Safe Operation	⑩ Power generations are simultaneously disconnected all together due to affection from another grid, etc.

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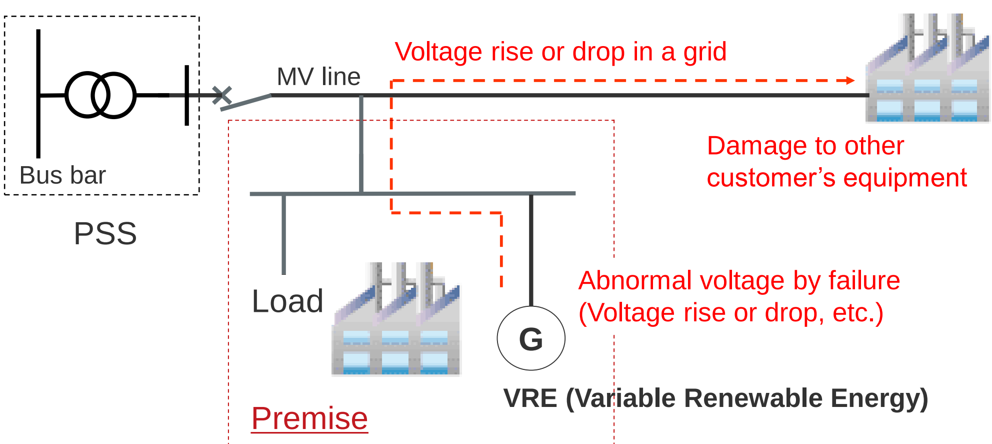
Grid protection quality (Supply reliability)

① Internal failure of VRE induces other customer equipment.

An internal failure of VRE may induce a bad affect such as device damage, etc. of other customers.



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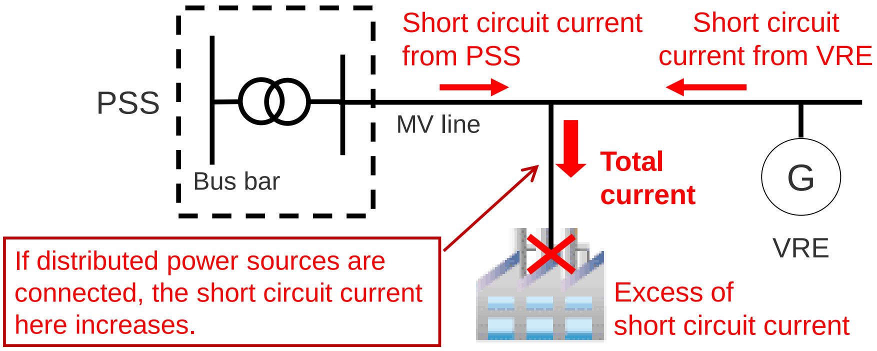
Grid protection quality (Supply reliability)

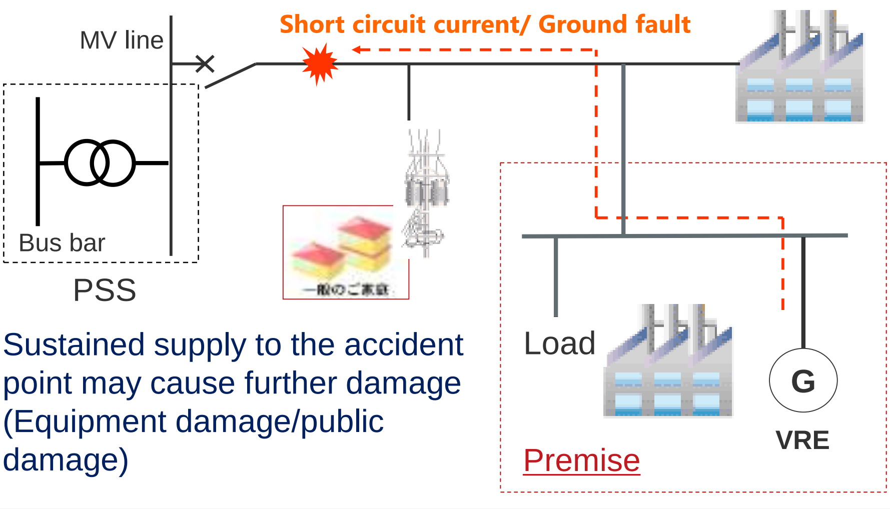
② Increase of short-circuit current by VRE induces the excess of that of equipment.

Since short-circuit current flows from both a substation and a VRE, the short circuit capacity (current) increases and may exceed the capacity limitation of a customer's equipment (may cause damage to the equipment).



Grid protection quality (Supply reliability)

③ Expansion of the accident by continuing to generate power from distributed power sources, in the event of a power system accident.

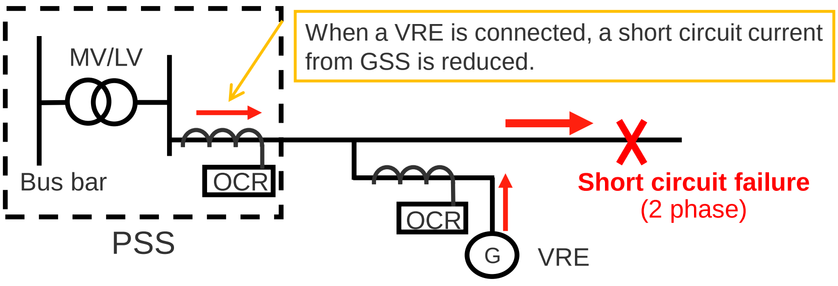


Sustained supply to the accident point may cause further damage (Equipment damage/public damage)

Grid protection quality (Supply reliability)

④ No OCR detection at a PSS induces more serous damage, in case of a failure in a grid.

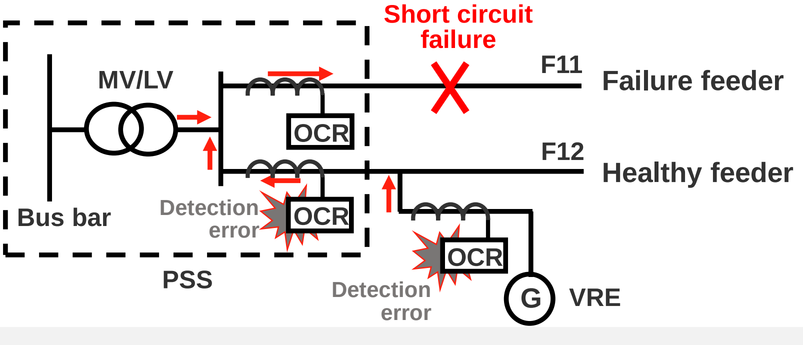
Due to the influence of the short-circuit current supplied from the distributed power source, the short-circuit current flowing out of the substation may decrease, and the substation OCR may not operate. As a result, the supply to the accident point may be continued and the damage may spread (equipment damage/public damage).



Grid protection quality (Supply reliability)

⑤ A detection error by OCR in other feeders induces additional power outages, in case of a failure in a feeder.

When a short-circuit failure occurs in a feeder near a GSS, OCRs in other feeders or private feeders might unnecessarily detect short-circuit current from DER (distributed energy resource) and induce additional power outages, because OCR has no direction. As a result, additional outage might occur in a healthy area.

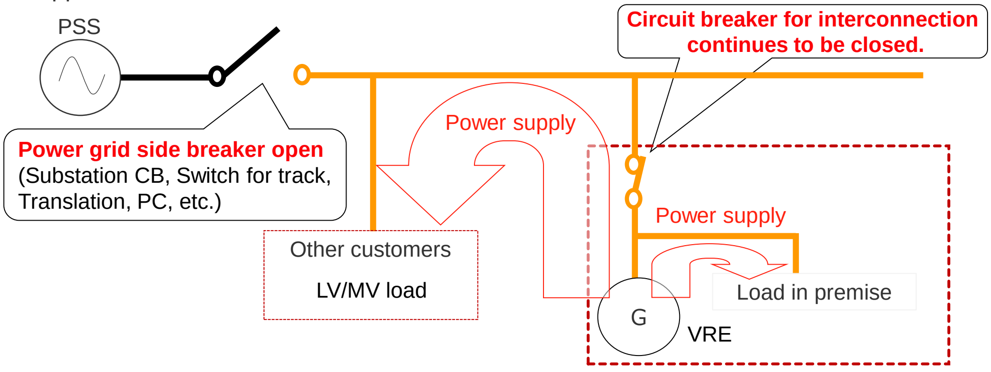


Safety and Equipment Maintenance

⑥ Only VRE continue to generate power independently, after a distribution grid is stopped.

VRE Islanding (Isolated operation)

When a part of the grid where the power generation equipment is interconnected is disconnected from the grid power supply due to an accident, work, etc., power generation is continued only by the distributed power supply existing in the relevant line, and power is supplied to the line load.



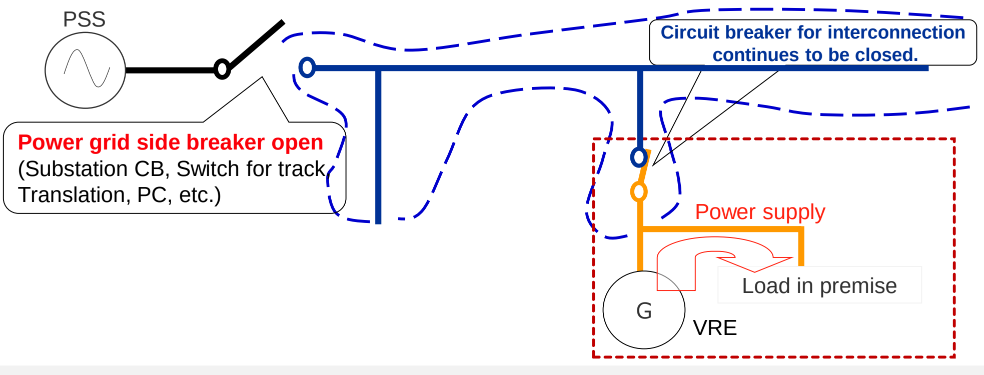
Safety and Equipment Maintenance

⑥ Only VRE continue to generate power independently, after a distribution grid is stopped.

VRE Reverse charge

In the state where there is no reverse power flow from the premises of VRE installer, only the voltage is applied from VRE to the point disconnected from the system power supply.

There is no reverse flow, but voltage is applied (charged) Special condition of islanding

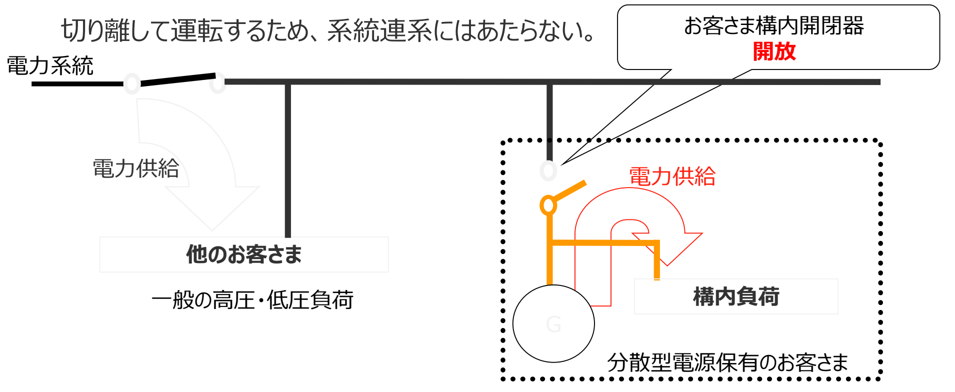


（参考）

■ 自立運転 ＯＫ

● 発電設備が**系統から解列された状態で、発電設備設置者構内の負荷のみに電力供給**をしている状態。

※一般的な非常用発電機は、発電時にはインターロック等により系統と完全に切り離して運転するため、系統連系にはあたらない。



Safety and Equipment Maintenance

⑥ Only VRE continue to generate power independently, after a distribution grid is stopped.

Situation where islanding/reverse charging

May occur, when the breaker of a distribution line is opened and the output of VRE and the load of the distribution line are almost balanced.

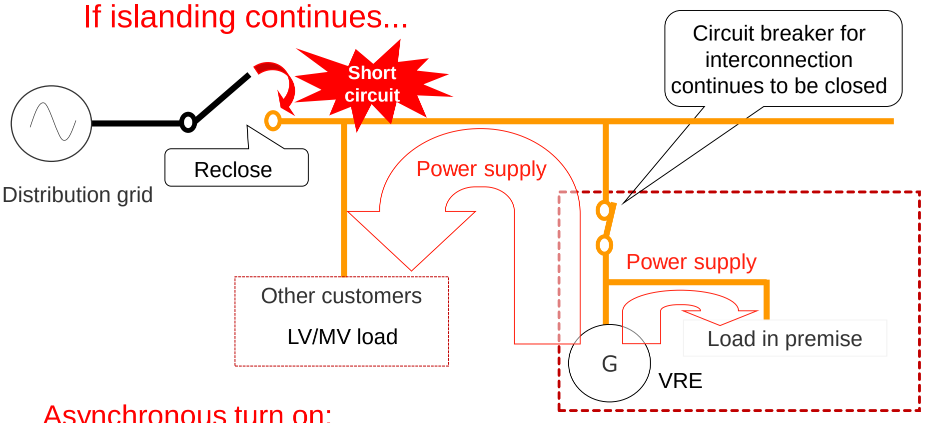
Problems by islanding and reverse charging	Potential risk
Equipment damage	◆ Damage to customer equipment due to frequency and voltage disturbances in the independent operation in the grid. ◆ Equipment damage due to continuous supply to the accident point ◆ Damage to customer equipment is damaged due to asynchronous input during reclosing
Public electric shock Worker's electric shock	◆ Public electric shock may occur due to continued accidents. ◆ The line that should be in blackout is charged, and the worker gets an electric shock.

It is necessary to detect VREs from the grid **promptly and reliably** by means of a protective relay or device, in the event of a power outage in the grid to which the power generation equipment is interconnected,

Safety and Equipment Maintenance

⑦ Equipment is damaged due to asynchronous closing (short circuit) when the distribution line is reclosed.

If islanding continues...

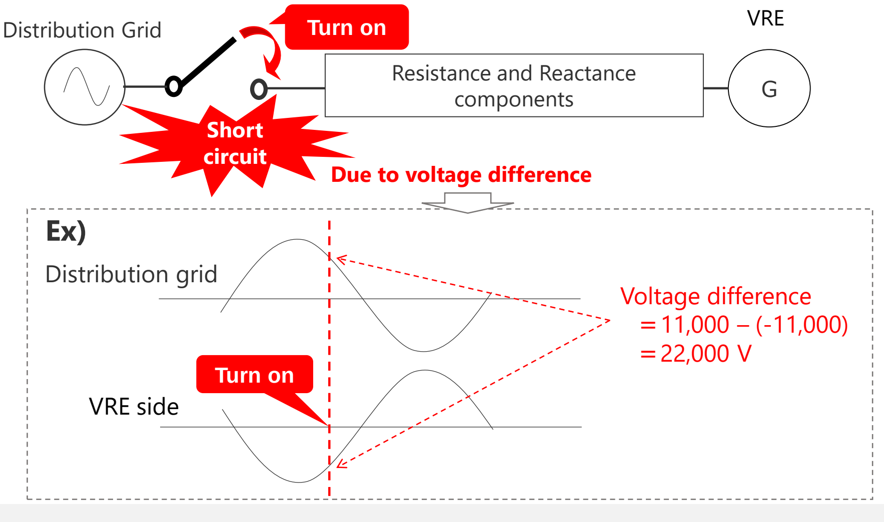


Asynchronous turn on:
Turn on when the voltage phases are out of phase. NG

Safety and Equipment Maintenance

Asynchronous turn on

If turn on when the voltage phases are out of phase,



Power Quality

⑧ VRE connection induces voltage fluctuation in a grid.

- Constant voltage fluctuation

  (LV) 101±6 V for 100 V class, 202±20 V for 200 V class

  (MV) Range for maintaining voltage of low voltage distribution system

- Instantaneous voltage fluctuation
  (Defined as fluctuation within 2 seconds by Grid interconnection code)

  Approximately within 10% of the ordinary voltage (90 V is the lower limit for LV)

> **Grid interconnection Code:**
> Information equipment such as computers and office automation equipment may be affected by equipment stoppages due to an instantaneous voltage drop of 10% or more of the rated voltage. Therefore, it is appropriate to suppress the instantaneous voltage drop during parallel disconnection to within 10%.

- Voltage flicker (Lighting flicker, etc.)

  $\Delta V10 \leqq 0.45$

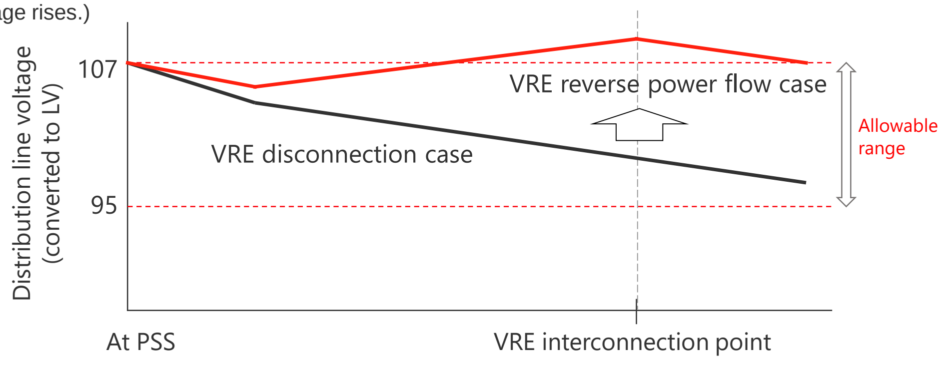
> ΔV10: Weighted with a qualified sensitivity filter that equivalently converts the fluctuation component of each frequency into the fluctuation of 10HZ, which is considered to be the most flickering by humans.

Power Quality

⑧ VRE connection induces voltage fluctuation in a grid.

When VRE with reverse power flow are connected to a grid, the reverse power flow may increase the grid voltage and may prevent the grid voltage from maintaining an appropriate value.

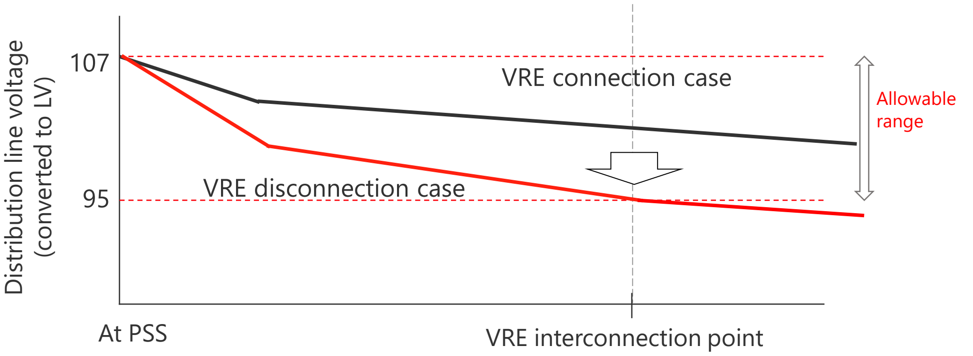
(As the grid current decreases due to reverse power flow, the voltage drop decreases and the grid voltage rises.)



Power Quality

⑧ VRE connection induces voltage fluctuation in a grid.

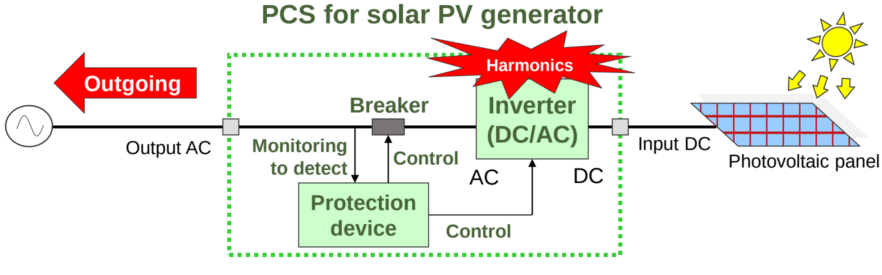
When the decentralized power supply is disconnected, the system current suddenly increases and a voltage drop occurs, which may prevent the grid voltage from maintaining an appropriate value.



Power Quality

⑨ Harmonic current flows from a VRE to a grid.

PCS for solar PV generator



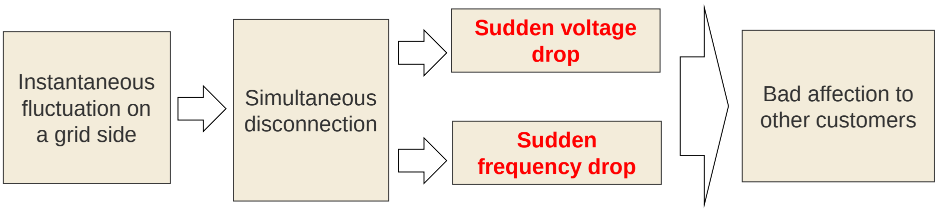
When installing the inverse converter (inverter), set the harmonic outflow current to the followings.

- Total current distortion: 5% or less
- Each current distortion: 3% or less

(Reference) Harmonic standard
HV: "Guideline for harmonic suppression measures for consumers receiving high voltage or extra high voltage"
LV: "JISC61000-3-2 harmonic current generation limit value"

Safe Operation

⑩ Power generations are simultaneously disconnected all together due to affection from another grid, changeover of grids, instantaneous voltage drop, sudden fluctuation of load, etc. Then, they cause affection to a grid quality, claim, etc.



The generator itself must meet the failure continuation requirements.
(FRT requirements)

- Prevent unnecessary disconnection
- Stable power generation

PCS (Power Conditioning System) Control

- DC-AC convertor
- Supply reactive power to decrease high voltage problem by PV

<u>Fundamental Protection function</u>

① **Prevent from isolated operation**

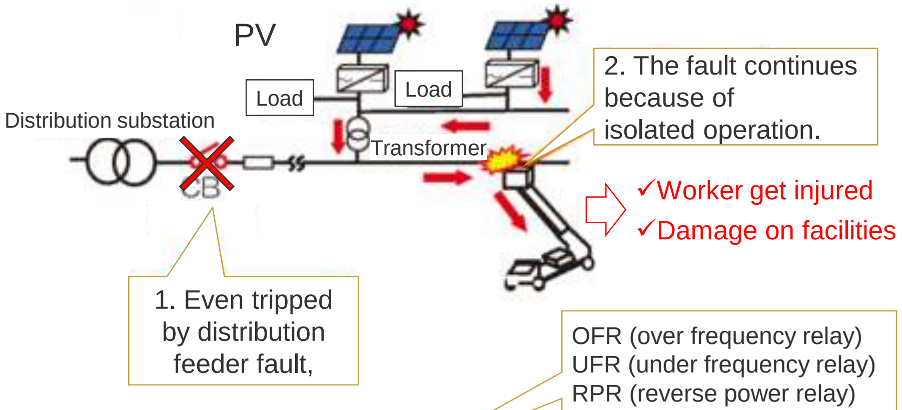
② **Prevent from unnecessary trip**

③ **FRT (Fault Ride Through)**

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

① Prevent from Isolated Operation (Islanding)

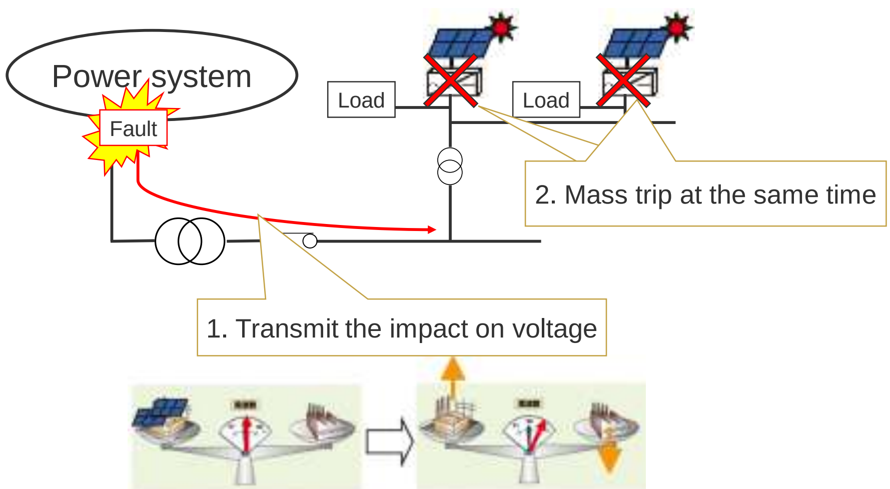
<u>Image of isolated operation in distribution system</u>



Isolated operation must be detected and PVs are disconnected immediately, according to the **Technical standards.**

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

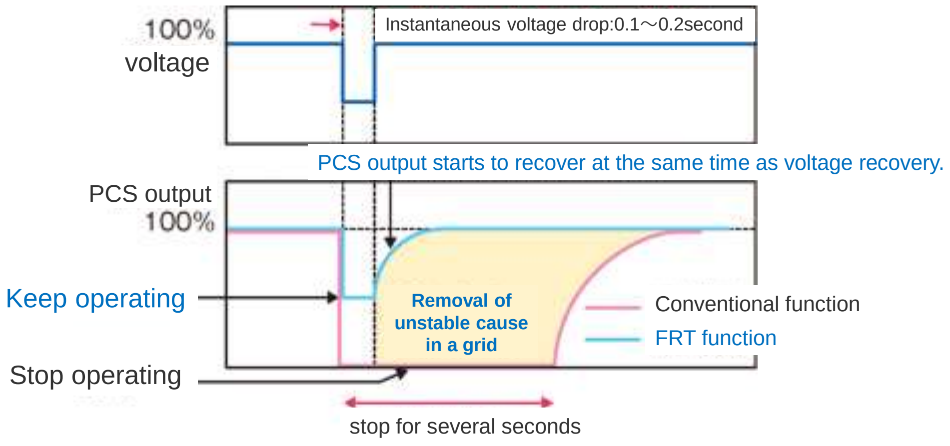
② Prevent from Unnecessary Trip



If supply demand balance gets lost, blackout might be occurred?

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

③ FRT (Fault Ride Through)



PCS output keeps operation and start to recover quickly as voltage recovery.

source: NEDO(new energy and industrial technology development organization) renewable energy technology white book ver.2

Technical Matters due to Mass VRE Introduction

Difficulty in Control of Distribution Grid State

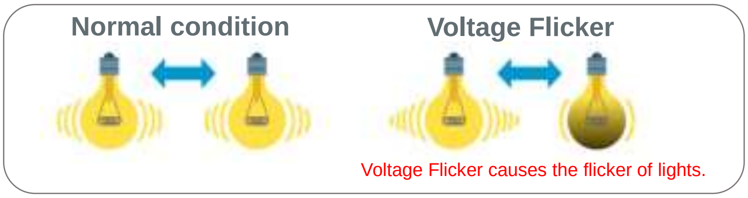
State (voltage & current) of a distribution grid is getting more and more difficult to control due to mass introduction of VRE, which makes grid planning and operation more and more difficult.

Ex) Voltage Excess and Fluctuation in Distribution Grid

Reverse power flow from VRE causes grid voltage rise, and may well exceed the limit stipulated by the Electric Utility Industry Law (101±6V in Japan). Also, output of PVs fluctuates according to weather conditions and other circumstances.

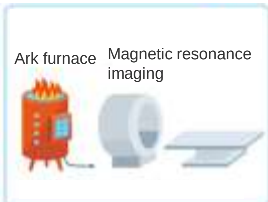
Voltage Flicker by PV Energy

Voltage Flicker happens by fluctuation of supply voltage.



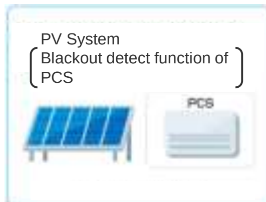
Previous reason

When power consumption changes rapidly,
Voltage flicker occurs locally.



Current reason

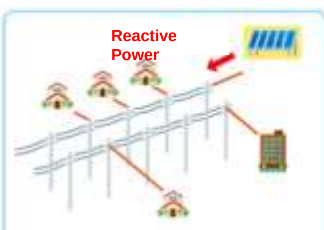
Under the condition of sunny days and low demand,
PCS setting of PVs causes wide range of voltage flicker.



Technical Matter of VRE Introduction

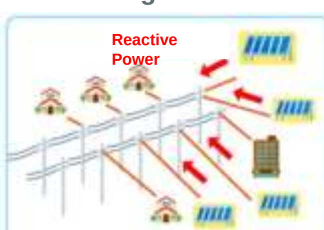
- ◆ PVs installation to a power grid increases rapidly.
- ◆ PVs connected to a power grid are required a disconnecting function, when a blackout happens in the grid.
- ◆ PVs supply reactive power to a power grid as this function (installed in the PCS).

Previous: Small amount of PVs



Influence of Reactive Power: **Small**

Current: Large amount of PVs



Influence of Reactive Power: **Large**

Load Fluctuation Suppression in VRE Matters

Effect by Storage Battery Introduction

Expectation effect	DD1	DD2	DD3	DD4	LECO
Shift peak load					
Prevent peak reverse power flow from exceeding facility capacity	Yes		Yes		
Suppress short-cycle load fluctuation	Yes		Yes	Yes	
Effective (low loss) power supply	Yes	Yes	Yes		
Improve low voltages in remote areas	Yes		Yes	Yes	
Keep voltage in an allowable range	Yes		Yes		
Control voltage to target values					

Where and what are higher priority matters?
What effects are expected by storage battery introduction?

Outline of Load Fluctuation Suppression Test

The fluctuations of output power/voltage in a distribution grid will be suppressed, by monitoring the power/voltage changes output from mass VRE and by charging and discharging power from a storage battery system in response to the monitored changes.

Load fluctuation suppression test

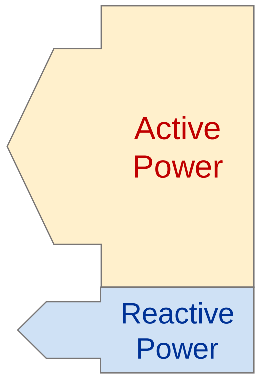
Test term	From May to July in 2022 (Tentative)
Test place	*** *** S/S, ** kV *** feeder (Max. demand: ***MW) *** city, *** Division, *** Province, Sri Lanka
Test facility	Power conditioning system (** kVA) Li-ion Battery? (** kWh), etc.
Test target	**To be selected based on the priority matters in Sri Lanka.** • Keep voltage in an allowable range • Improve low voltage in a remote area • Suppress short-cycle output power fluctuation • Prevent excess of peak reverse power flow • Control voltage to a target value • Shift peak load • Forecast PV generation, etc.

Countermeasures against VRE Matters

Effect by Storage Battery Introduction

What are expected by introducing **a storage battery system** against load fluctuation due to mass VRE installation?

1. Shift peak load
2. Prevent peak reverse power flow from exceeding facility capacity
3. Suppress short-cycle load fluctuation
4. Supply effective (low loss) power, etc.
5. Improve low voltage in a remote area
6. Keep voltage in an allowable range
7. Control voltage to a target value, etc.



Requirement for Safe and Stable Supply Reliability

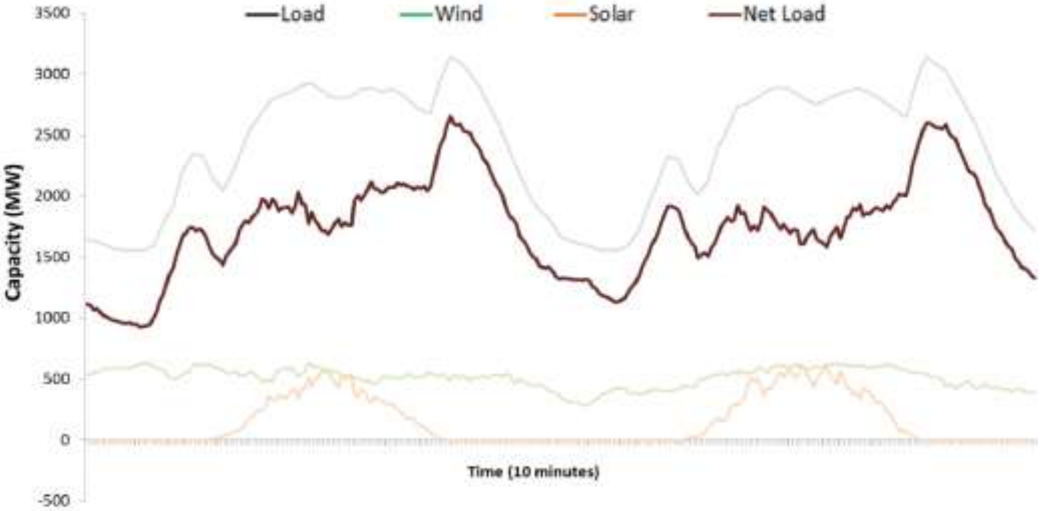
- Replacement due to overload

Classification	Normal	Contingency
33/36 kV	-6% ~ +6%	-10% ~ +10%
11/12 kV	-6% ~ +6%	-10% ~ +10%
230/400 V	-6% ~ +6%	-10% ~ +10%

- Voltage drop
  - 33/36 kV
  - 11/12 kV
  - 230/400 V

Facility	Loading rate criteria
Distribution line	70% for economy 125% for emergency
Distribution substation	80% for normal ?% for emergency
Primary substation	125% for overloading

Sample of Record of Output Power

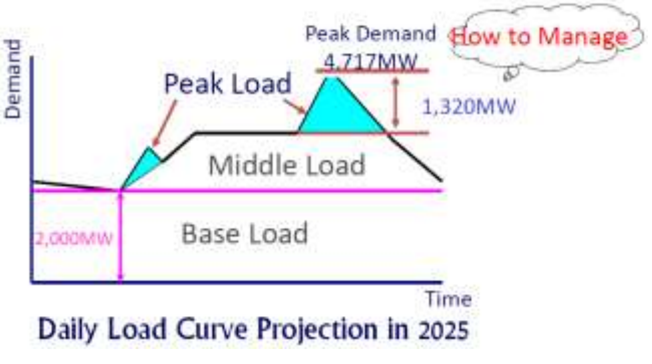


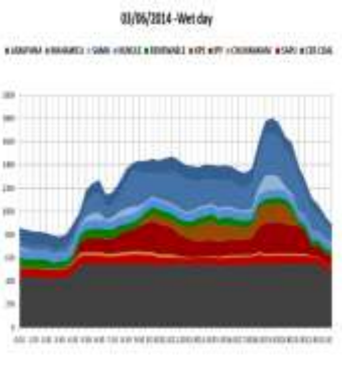
Each data of sunny, cloudy, rainy days, weekday and weekend

Peak Load Shift by Active Power Output

Improve the efficiency of the base load plants such as coal due to the off-peak restrictions by filling the valley of the Load curve. Feasibility is being done.

Low growth rate of off peak load could result energy curtailment and system stability issues with high penetration of variable renewable energy loads during off peak hours.

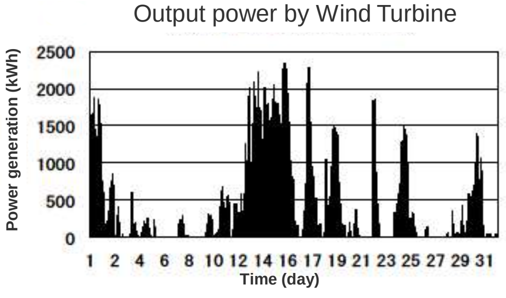


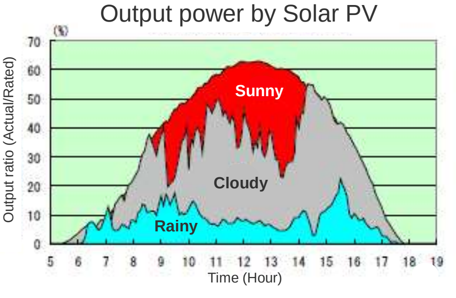


Fluctuation of Output power by PV/WT

Output power generated by PV and wind turbine is not stable due to the weather conditions such as wind conditions and solar radiation conditions.

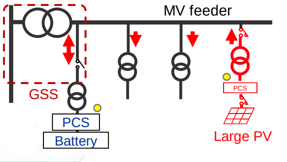
In addition, there is no supply and demand adjustment function for solar and wind power, and it is not possible to adjust the output according to demand.





Suppression of Power Fluctuation by Active Power Output

It can be seen that a storage battery has a certain suppression effect on the short-cycle fluctuation components due to PV generation in the output fluctuations on the secondary side of a substation.



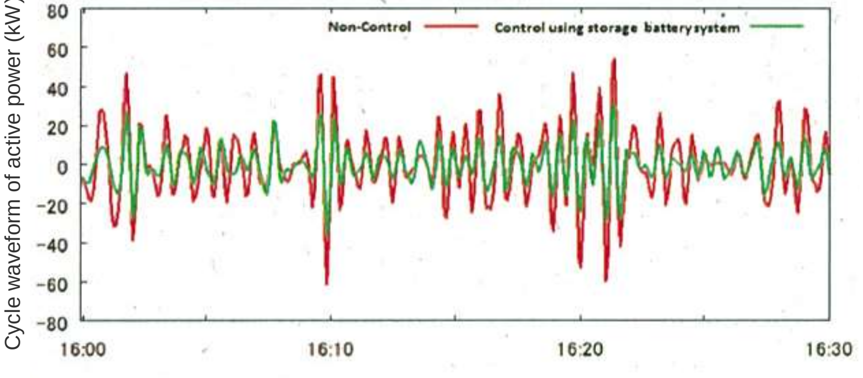


Fig. Control of active power fluctuation

Suppression of Voltage Fluctuation by Reactive Power Output

With respect to the voltage fluctuation on the secondary side of the substation, the reactive power is output from the storage battery system in the direction of suppressing the voltage fluctuation.

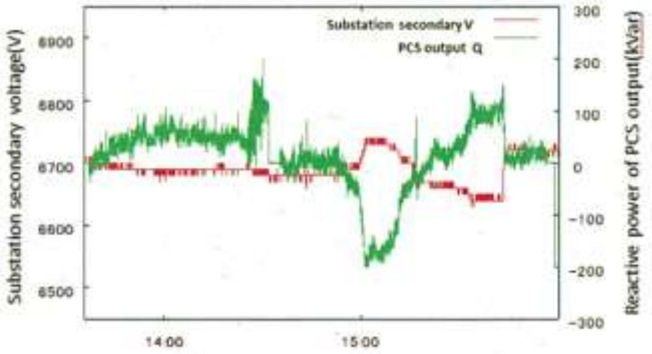


Fig. Suppression of voltage fluctuation at a secondary side of the substation

Short-cycle (less than a few minutes) voltage fluctuation, which cannot be suppressed by on-load tap changer of a transformer at a substation, can be suppressed and can reduce the operation number of an on-load tap changer for its long life.

Control to Target Voltage by Reactive Power Output

The voltage on the secondary side of a substation is controlled to be near the target voltage by reactive power output. When the reactive power capacity (from -200 kvar to +200 kvar) has a margin, a higher control effect is obtained.

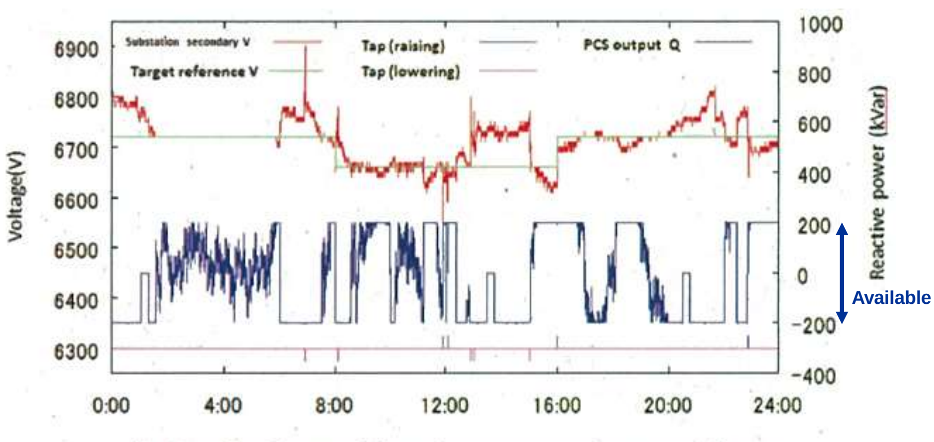


Fig. Control based on target reference voltage

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Utilization of BESS in Distribution Network and Aggregation with BESS and DR for Optimal System Configuration

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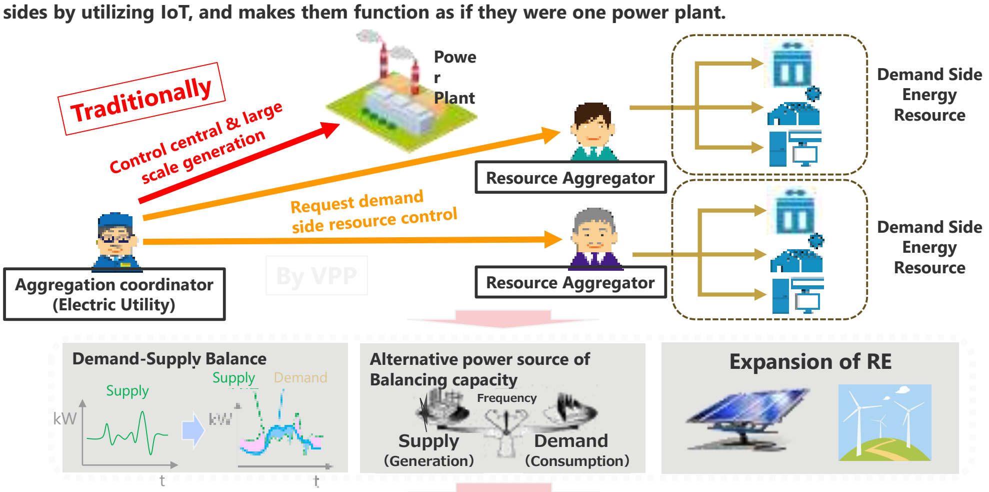
What is Virtual Power Plant (VPP)

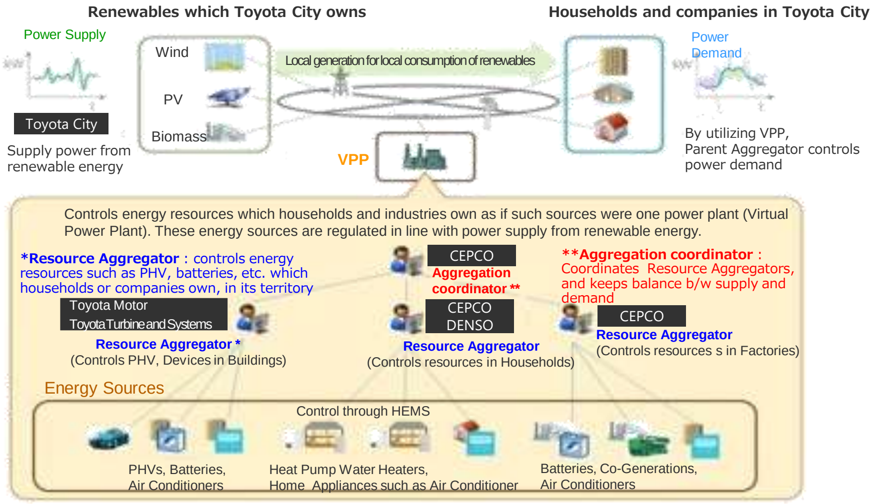
VPP means that aggregators (retailers) integrate and optimally control energy resources (PV, air conditioners, storage batteries, EVs, etc.) as "Energy creation", "Energy conservation" and "Energy storage" on customer sides by utilizing IoT, and makes them function as if they were one power plant.



・Decarburization ・Cost reduction of energy ・Improve energy self-sufficiency rate

Overview of Toyota city Virtual Power Plant Projects

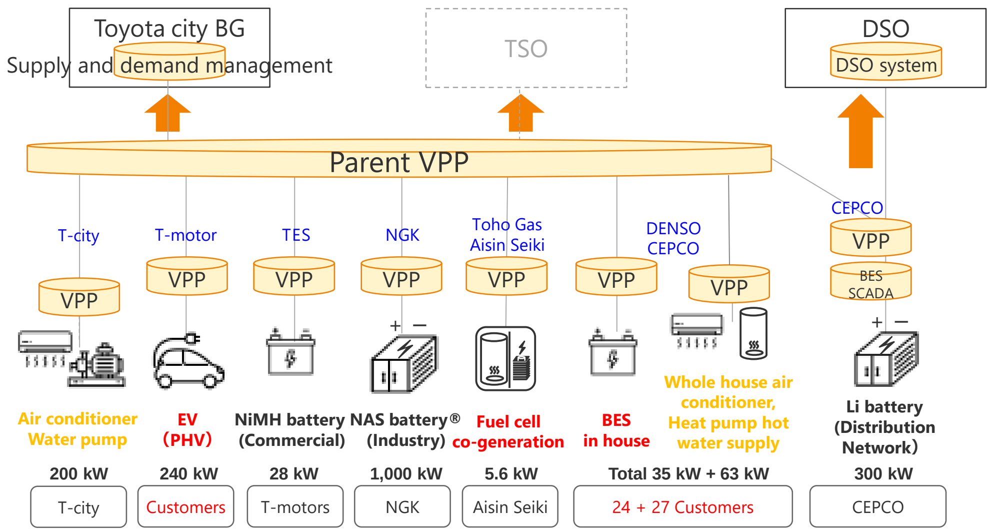
5 organizations of Toyota City, Toyota Motor Corporation, Toyota Energy Solutions, Denso, and CEPCO launched the VPP project as part of the "Local production and consumption of resources and energy" initiative, one of the themes of the Toyota City Council.



Theme of Virtual Power Plant Projects in Toyota city

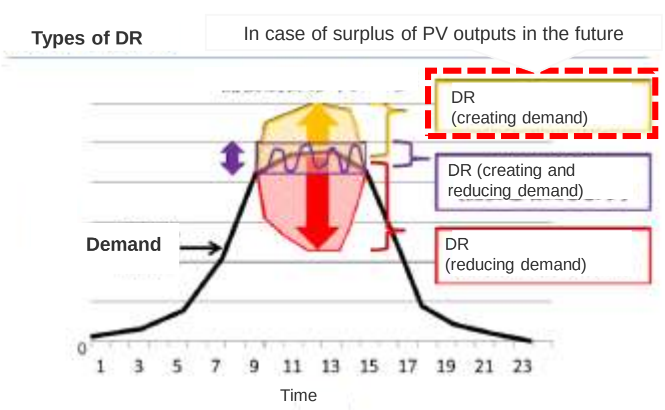
	Theme A : Control of distributed power sources		Theme B : Control of grid
	I. Utilization of DER to realize local production for local consumption	Ⅱ. Providing balancing control power to TSO/DSO	Ⅲ. Advancement of operation of the distribution system
Purpose	● Balancing b/w demand and supply	● Providing balancing control power to TSO/DSO	● Optimization of the distribution system ● Optimization of operation
Method	● Controlling power resources such as storage batteries, PHVs, heat pump water heaters, cogeneration units and so on	● Controlling storage batteries, cogeneration units and so on to provide TSO/DSO with balancing control power	● Controlling storage batteries to accommodate large amount of renewable energy
Remarks	● Toyota Motor Corp. participates as an aggregator and utilizes batteries in PHVs as distributed power sources.	● Try to provide 3 types of balancing control power to TSO/DSO and also conduct verification test of DR to create demand	● Achieve the optimal distribution system with using voltage adjusting equipment ● Consider optimal quantity and allocation of storage batteries

Formation of VPP Verification



Demand Response for Controlling Demand

- This project also verified the DR (Demand Response) performance to control demand
- DR for demand control was achieved through storing power to PHV or storage batteries, activating air conditionings, heat pumped water heaters and so on



出所) 経済産業省「デマンドレスポンスハンドブック～電気の使用量を賢く制御し、報酬を手に！～」

Utilizing DERs for achieving local production for local consumption

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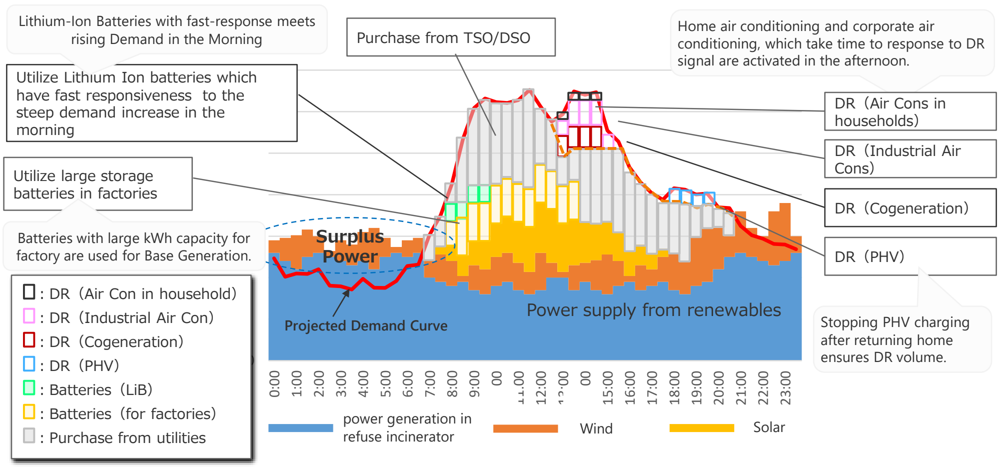
- Need to balance demand in the local area and supply mainly from renewables to achieve "local production for local consumption"
- To adjust the gap between demand and supply, utilize distributed power sources like BESS



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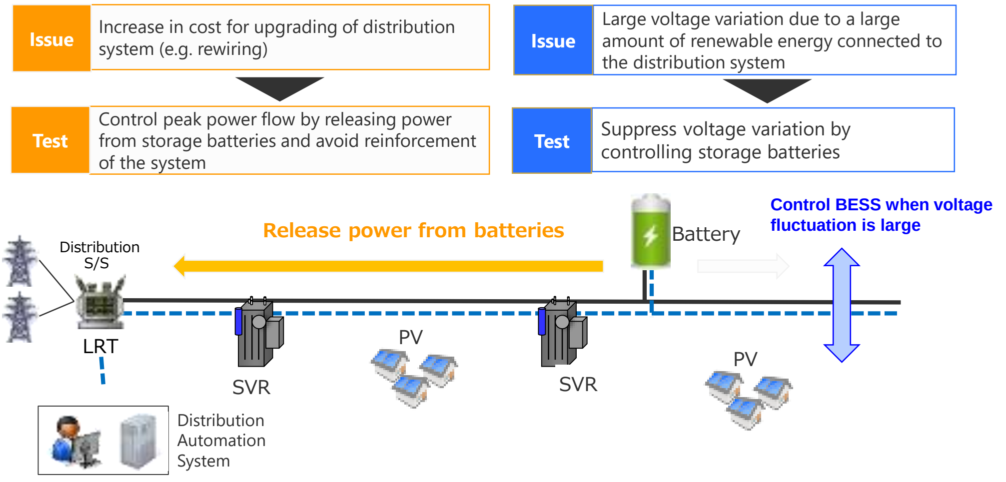
Utilizing BESS for Distribution Grid Operation

Verification of the possibility of achieving optimal distribution system configuration and the effect of suppressing voltage variation by controlling storage batteries



Economical Utilization of BESS in Distribution Network

Single purpose

- has to pay its full cost.
- should be compared to other countermeasures in the view of economical investment.

In case of suppression of voltage fluctuation, reactive power by SVC, etc. can compensate. (No need of active power in general)

Multi-purpose

- can cost less per purpose as the cost per purpose can be divided.
- leads to rational distribution facility formation in the future.

Overview of Demonstration System Environment

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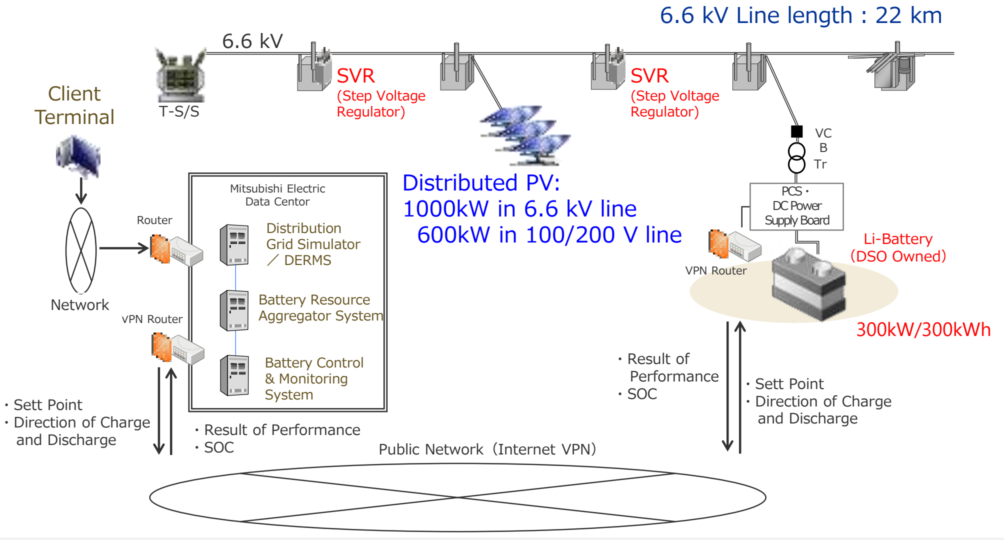

The Installed Battery Energy Storage System

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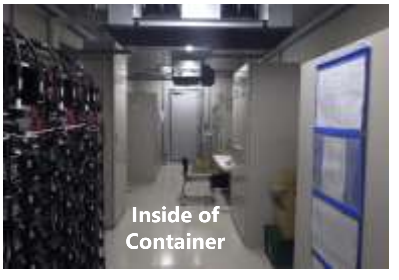
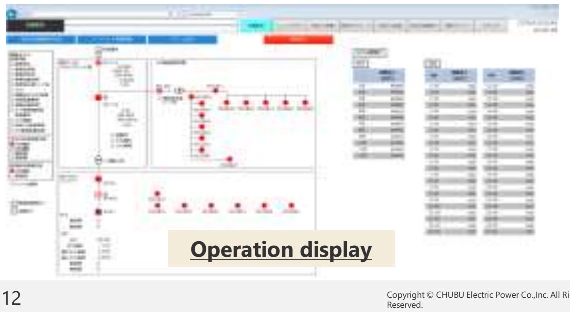
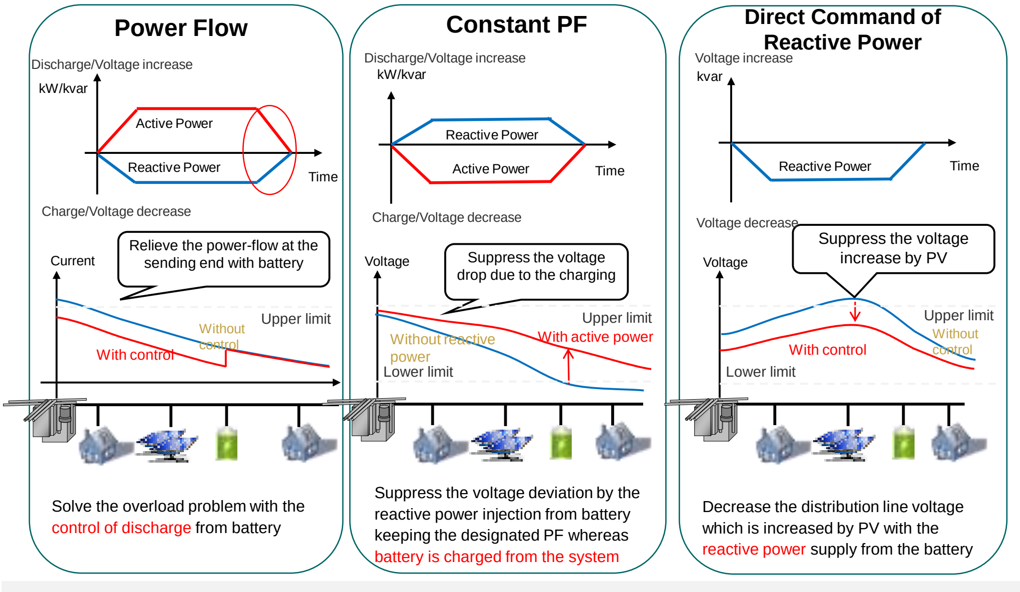




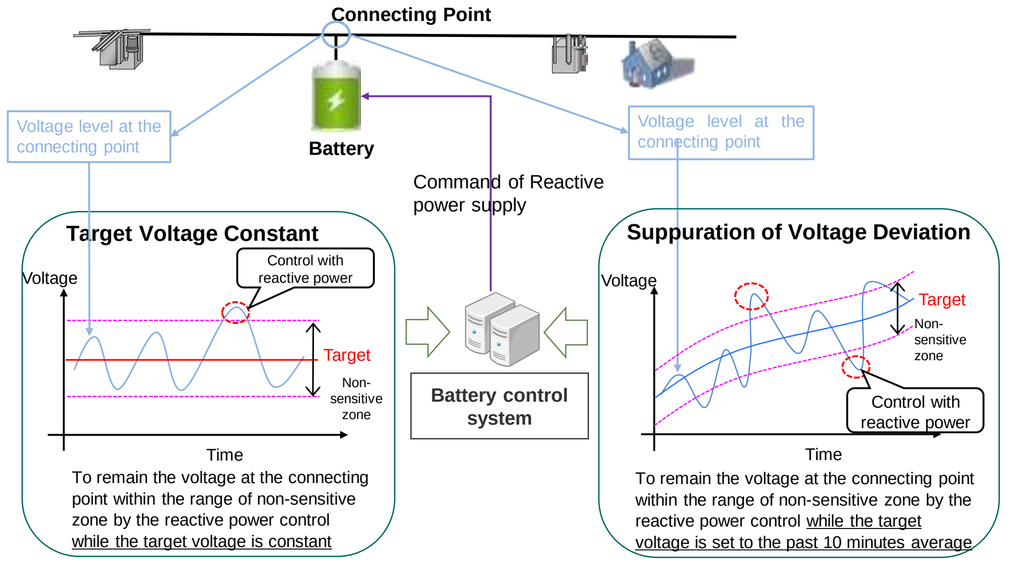
Use Cases of Demonstration

	Use Case	Use Case Scenario
①	Power Flow Control	A current overload occurs at the outgoing distribution line, when a part of the section of the next feeder is switched to the T-S/S F12 due to a failure. In order to control to avoid the current upper limit deviation, the active power of the BESS is output.
②	Reactive Power Control	Direct control of reactive power from the battery to avoid peak voltage excursions.
③	Constant Power Factor Control	In case of the battery dispatch the active power to adjust SOC and this may have a bad influence on the feeder, the battery carry out the constant power factor control to avoid voltage deviation.
④	Constant Target Voltage Control	In order to reduce the voltage deviation due to the deviation of PV output, the battery carry out the reactive power control to keep constant voltage. Confirming the possibility whether this solution contribute to reduce a voltage violation, or actuating cycle of SVR tap.
⑤	Control Voltage Violation	Likewise Constant Voltage Control, confirming the possibility whether the utilizing battery control contribute to reduce a voltage violation, or actuating cycle of SVR tap. With respect to the target voltage, by executing the moving average processing for the past 10 minutes, it is an object of the present invention to perform control for outputting the reactive power to the short term voltage fluctuation and suppressing the short period voltage fluctuation.

Utilization Purpose of BESS in Distribution Network by Power flow, Constant PF, Direct Command of Reactive Power

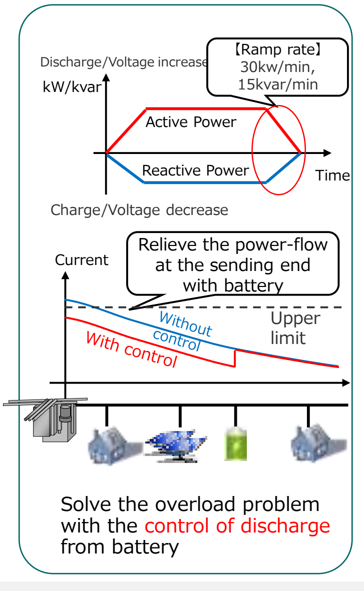


Utilization Purpose of BESS in Distribution Network by Target Voltage Constant, Suppuration of Voltage Deviation

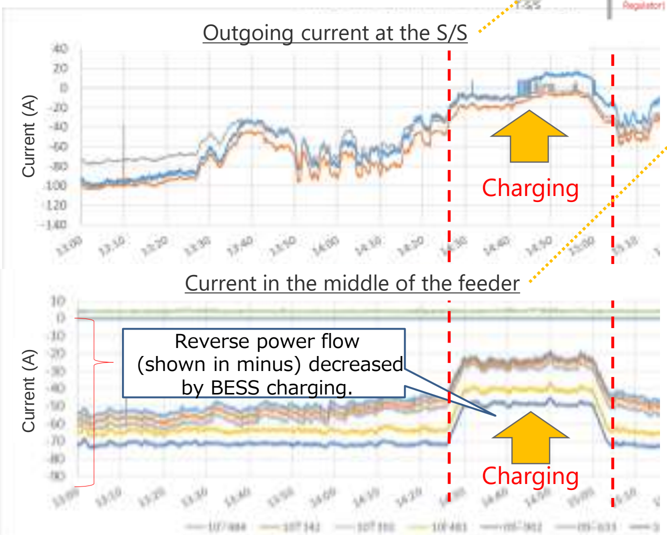


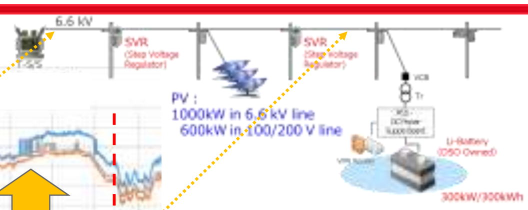
Control Type -Power Flow Control-

	Control type	Use Case Scenario
①	Power Flow Control	A current overload occurs at the outgoing distribution line, when a part of the section of the next feeder is switched to the T-S/S F12 due to a failure. In order to control to avoid the current upper limit deviation, the active power of the BESS is output.



Result of Power Flow Control

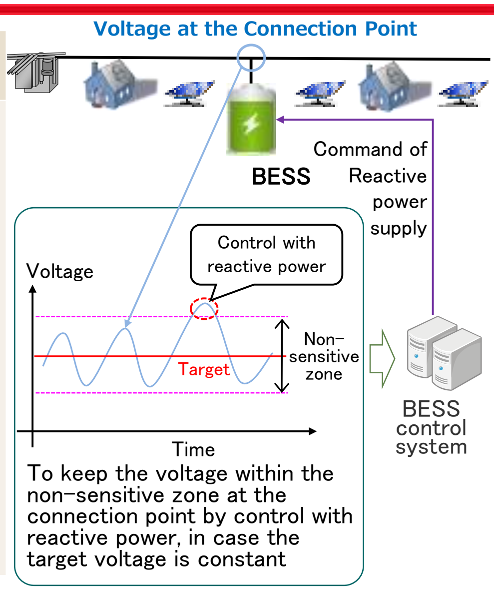




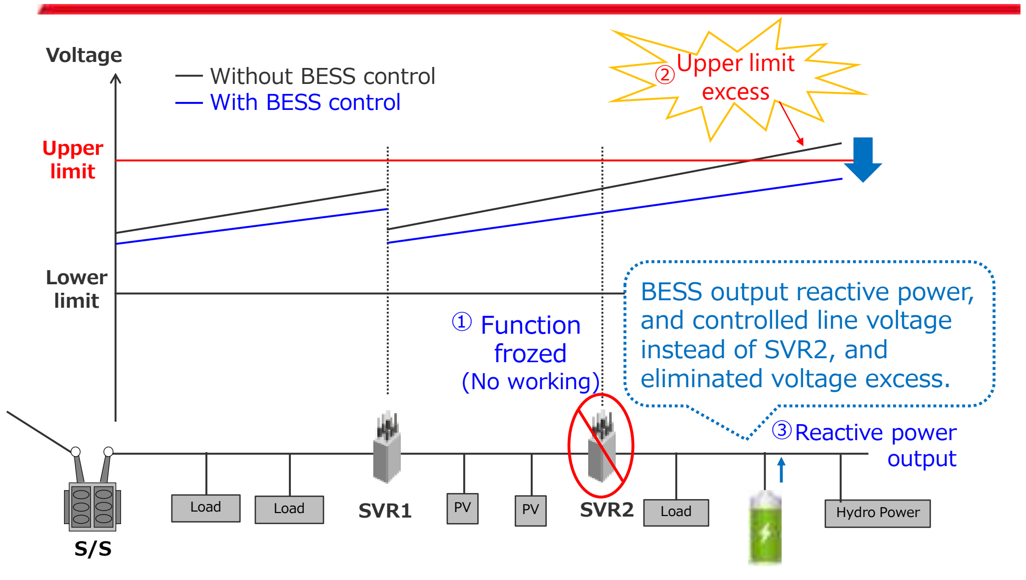
- 100 kW charging to the BESS from 14:30 to 15:00 Control the BESS in P.F.-0.8
- Decrease of the reverse power (current) was observed by BESS charging in the 6.6 kV feeder.

Control Type -Target Voltage Constant Control-

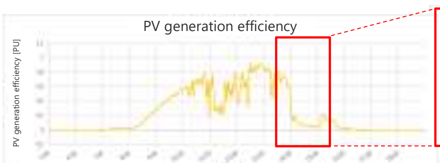
	Control Type	Use Case Scenario
④	Constant Target Voltage Control	In order to reduce the voltage deviation due to the fluctuation of PV output, the BESS carry out the reactive power control to keep constant voltage. Confirming the possibility whether this solution contribute to reduce a voltage violation, or frequency of SVR tap change.

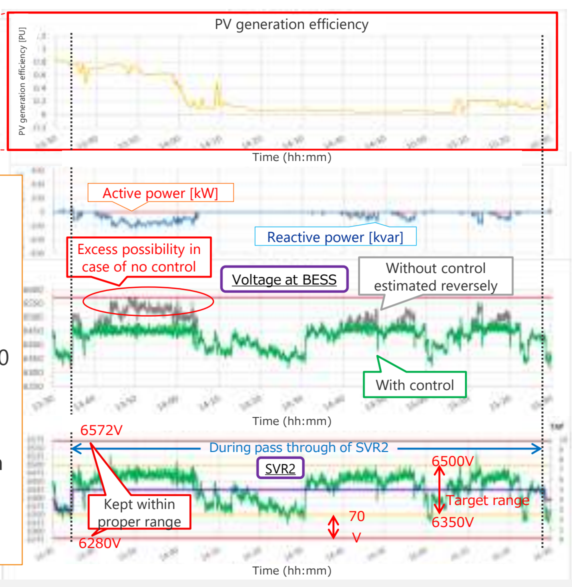


Result Image of Constant Target Voltage Control
- Verification of SVR Reduction Possibility-



Result of Constant Target Voltage Control
- Verification of SVR Reduction Possibility-

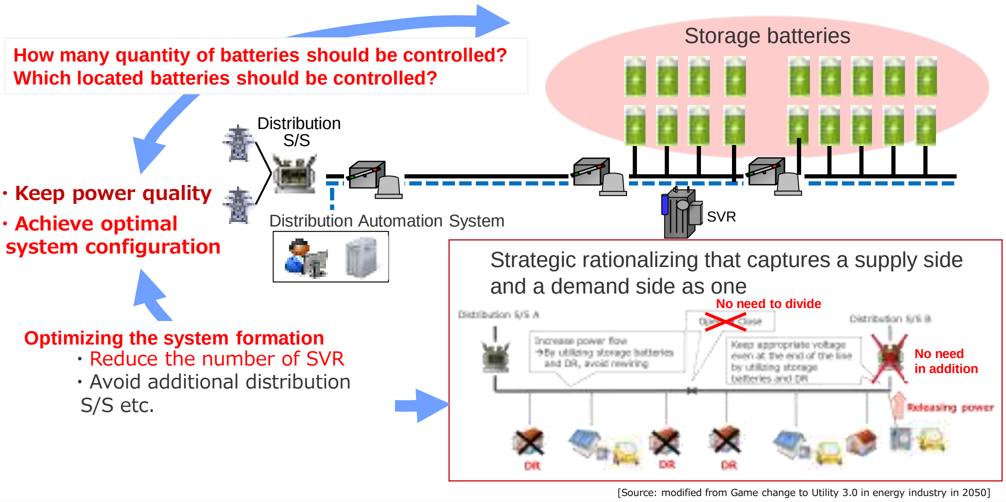




- From 13:30 to 15:30, SVR2 was set to pass through (the number of tap stage was 5), and the target voltage was tried to control to be constant.
- The parameter of constant target voltage control was set so that the SVR2 voltage was kept within the acceptable range (6350 to 6500V). As a result, it was maintained within the target (6280 to 6571 V).
- We were able to confirm a case where the distribution line voltage can be kept within the operating range and an SVR can be reduced by controlling the target voltage of the BESS at a constant level.

Rational distribution network formation

The optimal capacities and arrangement of BESS required for rational formation of distribution network will be studied, based on measurement data of power flow and voltage controlled by BESS, expecting the possibilities of BESS to be widespread in the future.



[Source: modified from Game change to Utility 3.0 in energy industry in 2050]

Conclusions in Distribution Network Verification

Regarding distribution network, the demonstration was conducted for the purposes of not only eliminating overload and suppressing voltage fluctuations but also rationalizing equipment by controlling the BESS.

- **Regarding power flow control, it was confirmed that the distribution line current was reduced by charging and discharging the BESS and the overload could be eliminated.**
- **Regarding constant target voltage control, it was confirmed that the BESS output reactive power against the fluctuations in solar PV output and the voltage was maintained stable.**
- **In addition, as a possibility of equipment rationalization using BESS, it was confirmed that it was possible to maintain the voltage of distribution lines within an appropriate operating range with an SVR off by the same BESS for eliminating overloading power flow.**
- **In the future, the studies for the actual operation of advanced distribution systems using BESS, etc. will be studied further.**

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1. Please answer the following questions on **VRE forecast system**

	Contents and Questions	Self Evaluation（Rating）	
(a)	Theme:Outline of VRE forecast method	Rating Before project	Rating at present
1	Were you able to get an idea of **General method of VRE forecast**		
2	Were you able to get an idea of **VRE forecast method and system configuration in CEPCO**		
3	Were you able to get an idea of **Development sites for VRE output forecast model in CEB**		
(b)	Theme:Structure of the wheather and VRE forecast model	Rating Before project	Rating at present
1	Were you able to get an idea of **Outline of VRE forecast model**		
2	Were you able to get an idea of **Way of thinking of the candidate of the VRE model development point**		
3	Were you able to get an idea of **Data and the acquisition method for the development of VRE forecast model**		
4	Were you able to get an idea of **the significance of collecting historical data such as weather observation and VRE output**		
(c)	Theme:Verification of accuracy of VRE forecast model	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Comparison result of the actual and the predicted value**		
2	Were you able to get an idea of **Review contents of the VRE forecast model on the basis of a verification result of the accuracy**		
3	Were you able to get an idea of **how to improve the accuracy of the VRE forecast**(e.g. reviewing wind power curve)?		
(d)	Theme:Structure of the VRE forecast model of the whole land of Sri Lanka from the VRE forecast model	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Structure of VRE forecast model of the whole Sri Lanka from the VRE forecast model**		
2	Were you able to get an idea of **how to extend the VRE point forecast to the area forecast**?		
3	Were you able to get an idea of **Development of VRE conversion tool** .		
4	Were you able to get an idea of **how to use the VRE Conversion Tool**		
5	Were you able to get an idea of **Validity evaluation of the VRE forecast model**		
(e)	Theme:Process of future VRE forecast	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Process of future VRE forecast** between before the project and at present.		
2	Were you able to get an idea of **the significance of acquiring the weather forecast data after the project**		
(f)	Please describe what contents impressed you among above contents, and what you would like to make use of in the future, and its reason.		
1			

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2. Please answer the following questions on **the Supply and Demand Operation against mass introduction of VRE**

(a)	Theme:RED(Renewable Energy Desk)	Rating Before Project	Rating at Present
1	Were you able to get an idea of **the Specification of VRE Control System**?		
2	Were you able to get an idea of **how to operate with 30 min. resolutions schedule**?		
3	Were you able to get an idea of **Technical Specification Details of PCS** ?		
4	Were you able to get an idea of **the role of RED**(Including other country's example)?		
5	Were you able to get an idea of **the VRE output Forecast system**?		
6	Were you able to get an idea of **the Chubu Renewable Management Function System Overview**?		
7	Were you able to get an idea of **the Future Configuration of RED**?		
(b)	Theme:How to estimate supply power of VRE	Rating Before Project	Rating at Present
1	Were you able to get an idea of **De-rating factor**?		
2	Were you able to get an idea of **EUE**?		
1	Were you able to get an idea of **how to handle self-connsumption in CEPCO**?		
(d)	Theme:System analysis using PSS/E	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Characteristic of the 1st, 2nd generation RE model**?		
2	Were you able to get an idea of **analysis method using the 1st, 2nd generation RE model**?		
(d)	Please describe what contents impressed you among above contents, and what you would like to make use of in the future, and its reason.		
1			

3. Please answer the following questions on **Grid Code revision**.

(a)	Theme:Sysem communication and control of VRE	Rating Before Project	Rating at Present
1	Were you able to get an idea of **necessity of newly describing system communication and control requirements with respect to VREs in Grid Code**?		
2	Were you able to get an idea of **the reason why VREs only with 10MW and more capacity are controllable**?		
3	Were you able to get an idea of **communication types between VRE control system and VRE resources**?		
(b)	Theme:RoCoF	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japan and Irelands' RoCoF**?		

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2	Were you able to get an idea of **evaluation methods of suitable criteria for Sri Lanka with PSS/E**?		
(c)	Theme:Power Factor Variation Capability	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japan and Irelands' Power Factor Variation Capability**?		
2	Were you able to get an idea of **evaluation methods of suitable criteria for Sri Lanka with PSS/E**?		
(d)	Theme:FRT	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japan and Irelands' FRT**?		
2	Were you able to get an idea of **evaluation methods of suitable criteria for Sri Lanka with PSS/E**?		
(e)	Theme:Specification of Thermal Generators	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japan and Irelands' specification requirements of Thermal Generators**?		
(f)	Theme:Ramp Rate Limitation	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japan and Irelands' Ramp Rate Limitation**?		
2	Were you able to get an idea of **evaluation methods of suitable criteria for Sri Lanka with PSS/E**?		
(g)	Theme:Control Prioritization	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Japanese Control Prioritization**?		
(h)	Please describe what contents impressed you among above contents, and what you would like to make use of in the future, and its reason.		
1			

4. Please answer the following questions on **Countermeasures for system stabilization.**

(a)	Theme: Current situation of electric power system against mass introduction of VRE	Rating Before Project	Rating at Present
1	Were you able to get an idea of **General issues in the electric power system by mass introduction of VRE**?		
2	Were you able to get an idea of **General countermeasures in the electric power system against mass introduction of VRE**?		
(b)	Theme:The characteristic of energy storage system	Rating Before project	Rating at present
1	Were you able to get an idea of **Outline of energy storage system**		
2	Were you able to get an idea of **Characteristics of battery storage system**		
3	Were you able to get an idea of **the virtual synchronization generator using the battery**?		

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4	Were you able to get an idea of **Characteristics of PSPP**.		
5	Were you able to get an idea of **operating example of the PSPP(Pumped Storage Power Plants) in Chubu Electric Power**?		
©	Theme:Comparison with battesy storage and PSPP	Rating Before project	Rating at present
1	Were you able to get an idea of **how to consider necessity capacity of PSPP and battery storage from supply and demand side.**		
2	Were you able to get an idea of **cost comparison between the battery storage and PSPP in long-term operation**		
(d)	Theme:Examination of the necessary battery capacity agains mass introduction of VRE	Rating Before project	Rating at present
1	Were you able to get an idea of **how to improve VRE ratio by controling each power plant output.**		
2	Were you able to get an idea of **Cost evaluation of instlation of energy storage system**.		
3	Were you able to get an idea of **how to improve SNSP(System Non-Synchronous Penetration)**.		
4	Were you able to get an idea of **how to evaluate of the cost for introduction of each battery storage capacity**		
5	Were you able to get an idea of **how to determine the introduction policy of energy storage system considering cost evaluation.**		

5. Please answer the following questions on **Development of PSPP.**

(a)	Theme:Issues of PSPP development	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Issues of PSPP development**?		
2	Were you able to get an idea of **General issues**?		
3	Were you able to get an idea of **Geologic issues of PSPP development in Maha3**?		
(b)	Theme:System analysis using Geological survey contents	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Existing geological survey result in Maha3**?		
2	Were you able to get an idea of **Geological survey contents in Victoria lake on the basis of a result of Maha3**?		
3	Were you able to get an idea of **Instructions at the time of the geological survey**?		
(c)	Theme:System analysis using Geological survey results	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Geological survey results in Victoria lake**?		

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2	Were you able to get an idea of **Instructions in the future geological survey**?		
3	Were you able to get an idea of **On-site training**?		
(d)	Theme:On-site training	Rating Before Project	Rating at Present
1	Were you able to get an idea of **On-site training**?		
(e)	Theme:Future issues	Rating Before Project	Rating at Present
1	Were you able to get an idea of **Future issues**?		
(c)	Please describe what contents impressed you among above contents, and what you would like to make use of in the future, and its reason.		
1			

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5 Please feel free to leave your comments and/or suggestions on the Project:

Thank you for your kind cooperation.

Short Test

01 Abrasion Resistance Cover for Conductor (ARC)

Abrasion Resistance Cover for Conductor

CHUBU Electric Power
NIPPON KOEI

1． What is the most effective location to install the ARC?

Answer：

2． What does ARC mean? (select one)
- Abrasion resistance
- Corrosion resistance
- Heat resistance

3． How do you determine when to replace an ARC? (select one)
- every 1 year
- every 3 years
- when yellow layer shown
- when holes are shown

4． Which distribution lines is the ARC provided under this project applicable to? (select one)
- Less than 33kV
- Less than 11kV
- Less than 0.4 kV

Abrasion Resistance Cover for Conductor

5． How many layers does ARC have? (select one)
- Two layers
- Three layers
- Four layers

6． What color is the second layer of ARC? (select one)
- Red
- Yellow
- Green

7． What should be the top priority for countermeasures when MV lines are in contact with trees? (select one)
- ARC installation
- MV line rerouting
- Tree trimming

8． What are the reasons for the above answers?

Answer：

02 Over Current Indicator (OCI)

Over Current Indicator

CHUBU Electric Power
NIPPON KOEI

1． Which indicator values does OCI improve? （select one）
- SAIDI
- SAIFI
- Both

2． What is the most effective area or location to install OCI?

Answer：

3． On which side of the area you want to omit patrols is it more effective to install OCI? (select one)
- Primary Side
- Load Side

4．

4－1 Select one of the following correct statements.
The OCI provided under this project is….
- Battery-powered, so they need to be replaced when the batteries run out.
- Maintenance-free because it is powered by solar cells.
- Maintenance-free because it is operated by electromagnetic induction.

Over Current Indicator

4－2 Select one of the following correct statements

- When overcurrent passes through the OCI, OCI shines.
- When an overcurrent passes through the OCI, the OCI sounds.
- When an overcurrent passes through the OCI, the display color of the OCI changes.

4－3 Select one of the following correct statements

- After the OCI detects an overcurrent, it is necessary to replace the OCI.
- After the OCI detects an overcurrent, the OCI will automatically reset in about 5 hours.
- After the OCI detects an overcurrent, the OCI will automatically reset in about 1 day.

4－4 Select one of the following correct statements

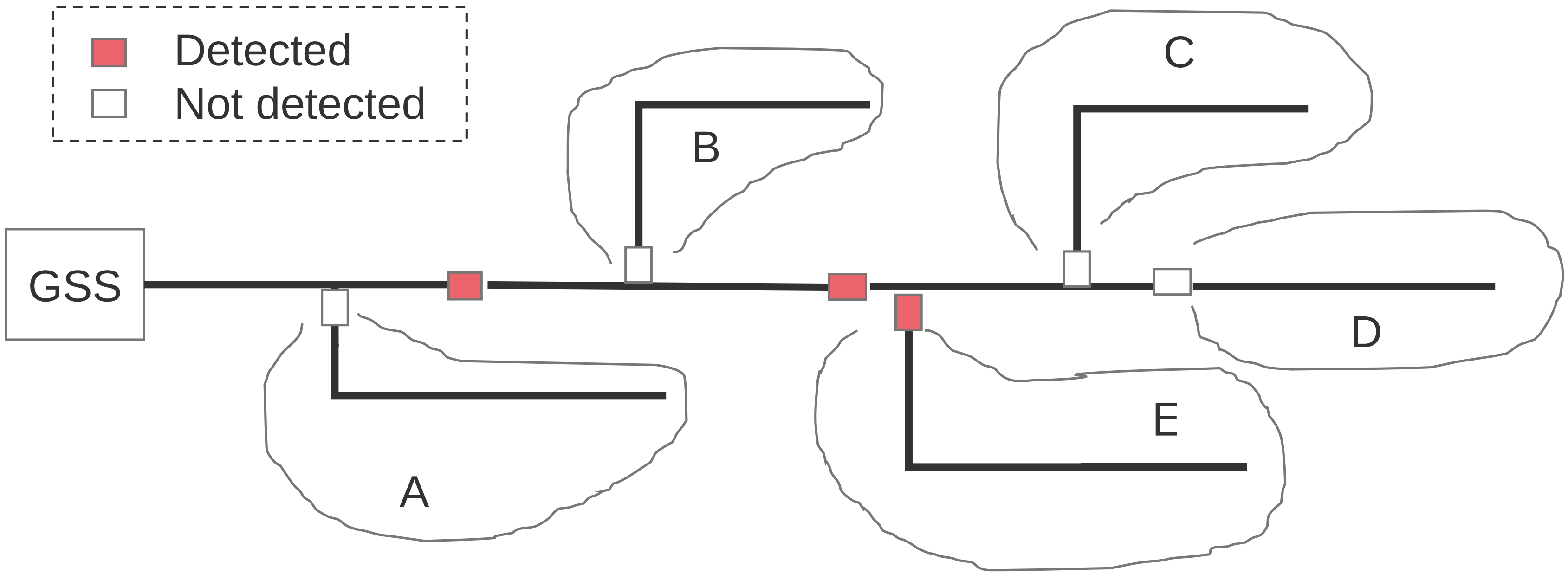
Condition: OCI capacity is 300 A

Detecting overcurrent for more than the operating time

- When an overcurrent of 330A is detected, the unit may not operate.
- When an overcurrent of 280 A is detected, the unit may not operate.
- When an overcurrent of 250 A is detected, the unit may not operate.

Over Current Indicator

5． If the OCI operates as described below, choose all areas that can be omitted from the patrol.（Answer with Alphabet）
※However, except in the case of frequent multiple lightning strikes, there should be only one cause of failure.



Answer：

03 Ground Fault Detector (GFD)

Ground Fault Detector

1． Which indicator values does GFD improve? （select one）
- ・SAIDI
- ・SAIFI
- ・Both

2．

2－1 Select one of the following correct statements
- ・GFD applies DC pulse voltage to detect fault location.
- ・GFD applies AC pulse voltage to detect failure locations.

2－2 Select one of the following correct statements
- ・When an earth fault current flows to the CT Receiver, the receiver glows.
- ・When the earth fault current flows to the CT Receiver, a sound is emitted.
- ・When an earth fault current flows to the CT Receiver, the receiver glows and a sound is emitted.

2－3 Select one of the following correct statements
- ・GFD only needs to check 1 phase.
- ・GFD only needs to be checked on 2 phases or 1 phase.
- ・GFD needs to check all three phases.

Ground Fault Detector

2－4 Select one of the following correct statements

- GFD cannot detect internal arrester failures that cannot be visually confirmed.
- GFD can calculate the distance from the detection point to the failure point.
- GFD is a device that divides a faulty feeder into two parts, determines which is the faulty area, and repeats this process to gradually narrow down the faulty area.

2－5 Select one of the following correct statements

- GFD is effective in locating OC faults.
- GFD is effective in locating EF failures.
- GFD is effective in locating OC and EF failures.

04 Fault Location System (FLS)

Fault Location System

1． Which indicator values does FLS improve? （select one）
- SAIDI
- SAIFI
- Both

2． Which of the following events requires changing the line constants registered in the FLS?(Select all)

- Rerouting of power lines from one line to another
- Conversion to thicker wires(same route)
- Replacement of wires (same thickness)
- Relocation of AR without system change
- Extension of distribution lines
- Shortening of distribution lines
- Changing the capacity of a pole transformer

Fault Location System

CHUBU Electric Power
NIPPON KOEI

3．

3－1 Select one of the following correct statements

- The FLS needs to be installed at several locations on the incoming distribution lines.
- The FLS needs to obtain the current and voltage of the target feeder at the substation.
- The FLS needs only the trip and relay information of the CBs in the substation.

3－2 Select one of the following correct statements

- The FLS can detect the distance between the fault point and the section switch on its power supply side.
- The FLS can detect the distance between the fault point and the substation.
- The FLS can display the location of the fault point on a map.

3－3 Select one of the following correct statements

- FLS is effective in detecting OC faults.
- FLS is effective in detecting EF failures.
- FLS is effective in detecting OC and EF failures.

05 Time Sequential Sectionalizer

Time Sequential Sectionalizer

1． Which indicator values does TSS improve? （select one）

・SAIDI

・SAIFI

・Both

2．

2－1 Select one of the following correct statements

・Substation CB is required to be reclosed once.

・Substation CB is required to be reclosed twice.

・Substation CB is required to be reclosed 3 or more times.

2－2 Select one of the following correct statements

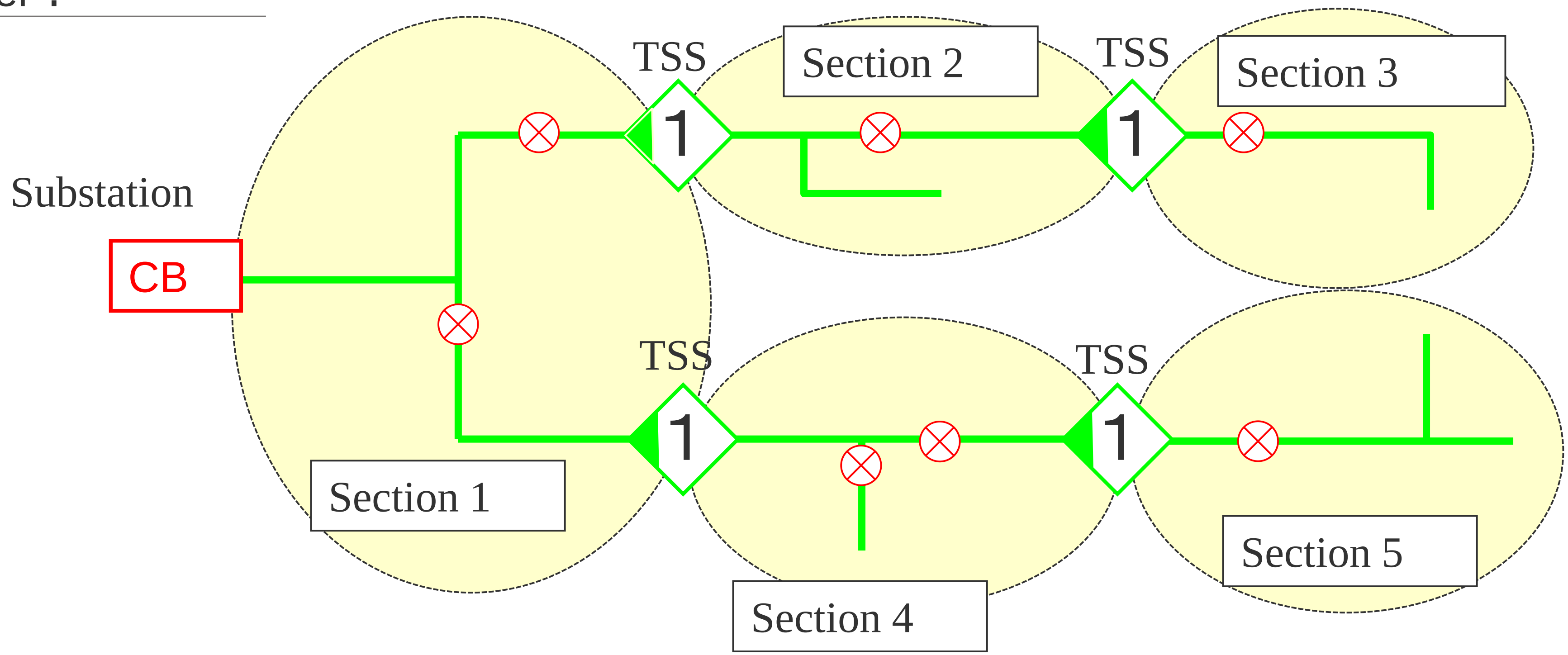
・Not applicable if there is a communication line on the line.

・Applicable only when there is a communication line on the line.

・Applicable whether or not there is a communication line on the line.

3． If the substation re-tripped 28 seconds after it was first reclosed, at which section have the point of failure occur? ※ TSS operates every 9 seconds.

Answer：



4． In this case, answer all sections that are automatically re-charged when the circuit is second reclosed.

Answer：

06 Various power outage countermeasures

Classification of measures to improve supply reliability

1． Select from the word group the countermeasure that corresponds to the number in the table below. ※Answer with Alphabet.

Word Group

A:Inspection synchronized with construction
B:Enclosed cutout
C:Ground fault detector
D:Over Current Indicator
E:Overhead ground wire
F:Transformer bushing cover
G:Abrasion resistance cover
H:Automatic fault section detection system with time sequential sectionalizer

			Countermeasures
Power failure counter-measures	Measures for early power recovery [related to SAIDI]	Automation of power restoration to sections without failure	1 :
		Narrow down the patrol area	・Fault section locator 2 : 3 :
	Failure reduction measures [related to SAIFI]	lightning	・Insulation coordination by insulators ・Lightning cutout ・Lightning horn ・Lightning arrestor 4 :
		Contact with other objects such as birds, snakes, and trees	・Bird/snake protection cover 5 : 6 : 7 :
		Insufficient facilities, Inadequate maintenance	8 :

WG3-2: Examination on Load Fluctuation Suppression

Examination No. in WG3-2

<Voltage fluctuation>

1. Answer whether the following is Y(correct) or N(wrong).
   - ➢ Maximum voltage drop can be checked by measuring not all the three phases but one of the three phases in a distribution line.

Circle Y or N

<Voltage fluctuation>

2. Circle the correct number of the followings in case that there are lots of DERs (distributed energy resources) in a distribution line.
   ① Voltage at a power grid side is always higher than that at a load side.
   ② Voltage at a power grid side is always lower than that at a load side.
   ③ Voltage at a power grid side is higher than that at a load side in case there is a reverse power flow.
   ④ Voltage at a power grid side is lower than that at a load side in case there is a reverse power flow.

Examination No. in WG3-2

<VRE countermeasures>

3. Circle all the correct numbers of the followings which can improve the voltage fluctuation by VRE(variable renewable energy) as countermeasures in distribution lines.

① SVR (step voltage regulator)

② SVC (static var compensator)

③ BESS (battery energy storage system)

④ Additional transformer to divide a power supplying area

⑤ Replacement of conductor to thicker one

⑥ Additional conductor along the existing conductor

⑦ DR (demand response)

⑧ EV (electric vehicle) interconnection

Examination No. in WG3-2

< VRE countermeasures>

4. Circle all the correct numbers of the followings which can improve the current excess by VRE(variable renewable energy) as countermeasures in distribution lines.

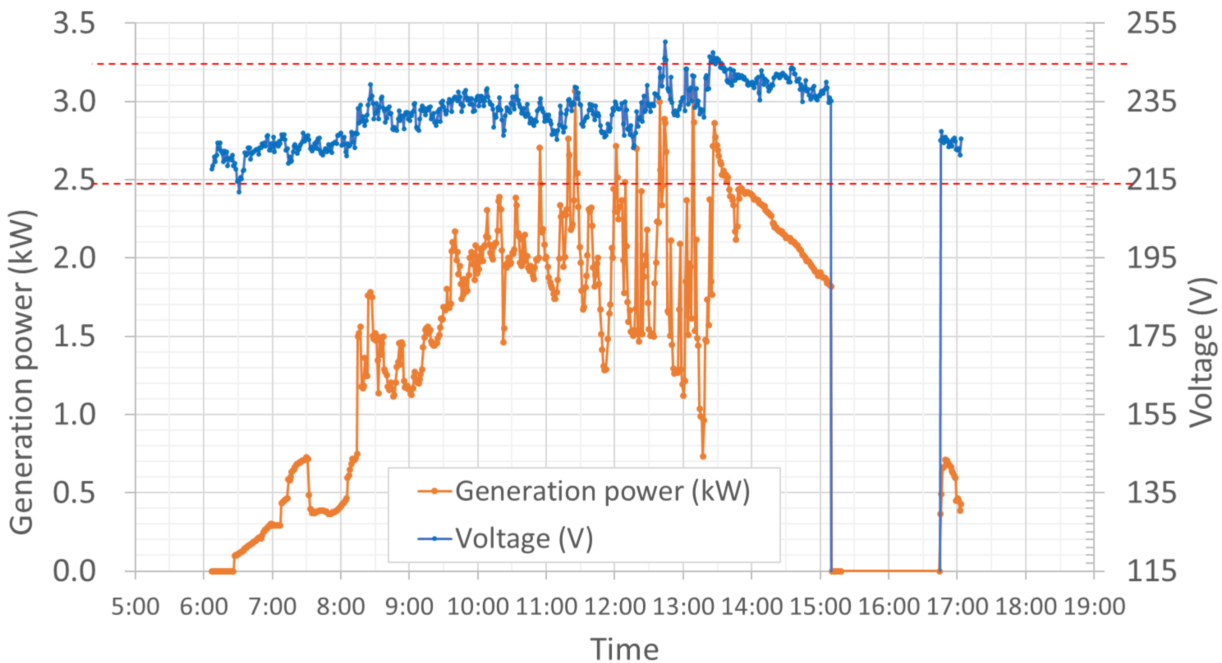
① SVR (step voltage regulator)
② SVC (static var compensator)
③ BESS (battery energy storage system)
④ Additional transformer to divide a power supplying area
⑤ Replacement of conductor to thicker one
⑥ Additional conductor along the existing conductor
⑦ DR (demand response)
⑧ EV (electric vehicle) interconnection

<Measurement>

5. Answer whether the following is Y(correct) or N(wrong) regarding the figure showing the voltage and power output by a solar PV generator.

- ➢ The weather changed from sunny to rainy around 16:00.

Circle Y or N

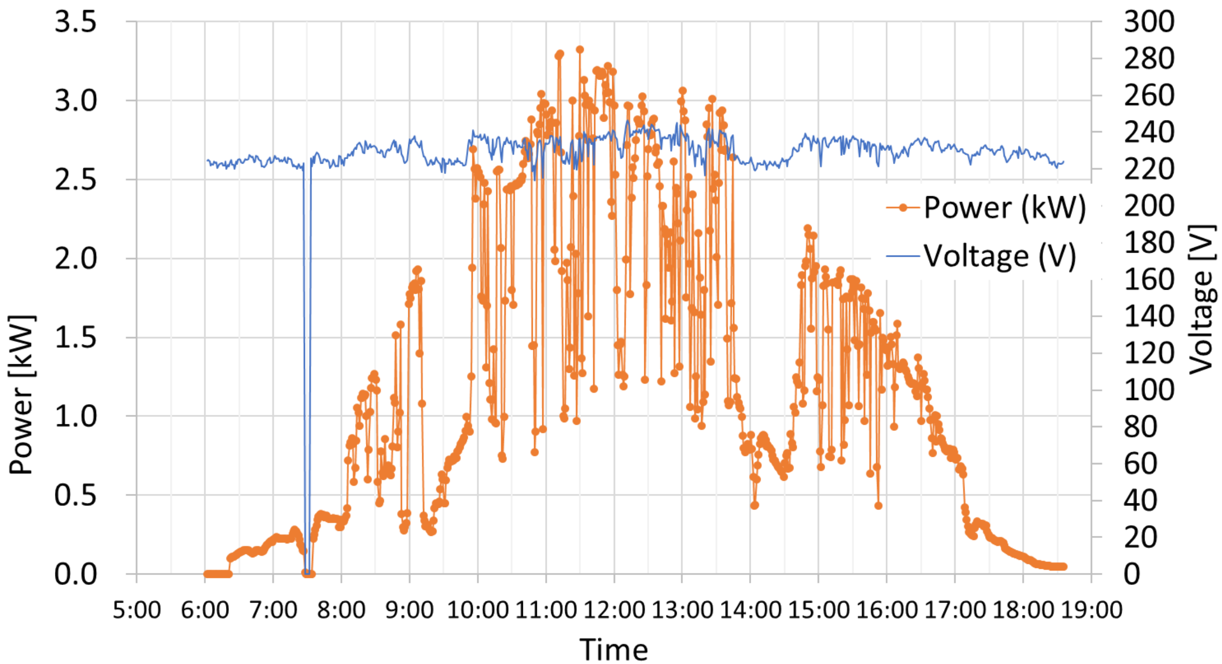


Examination No. in WG3-2

< Measurement>

6. Answer whether the following is Y(correct) or N(wrong) regarding the figure showing the voltage and power output by a solar PV generator.
   - ➢ There is a power outage around 14:00.

Circle Y or N



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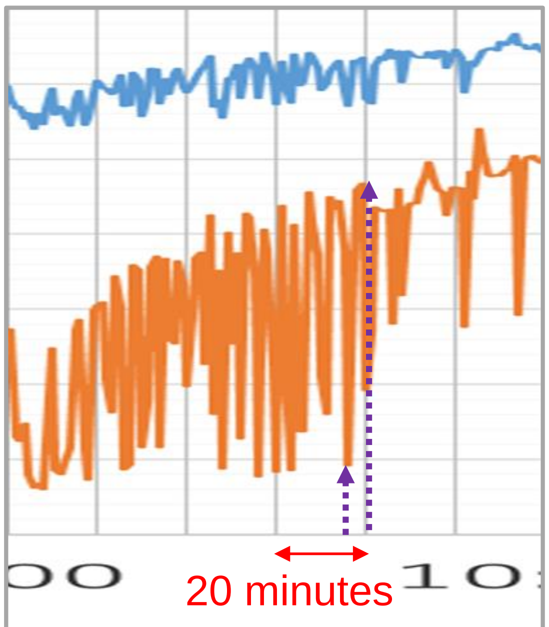
<Measurement>

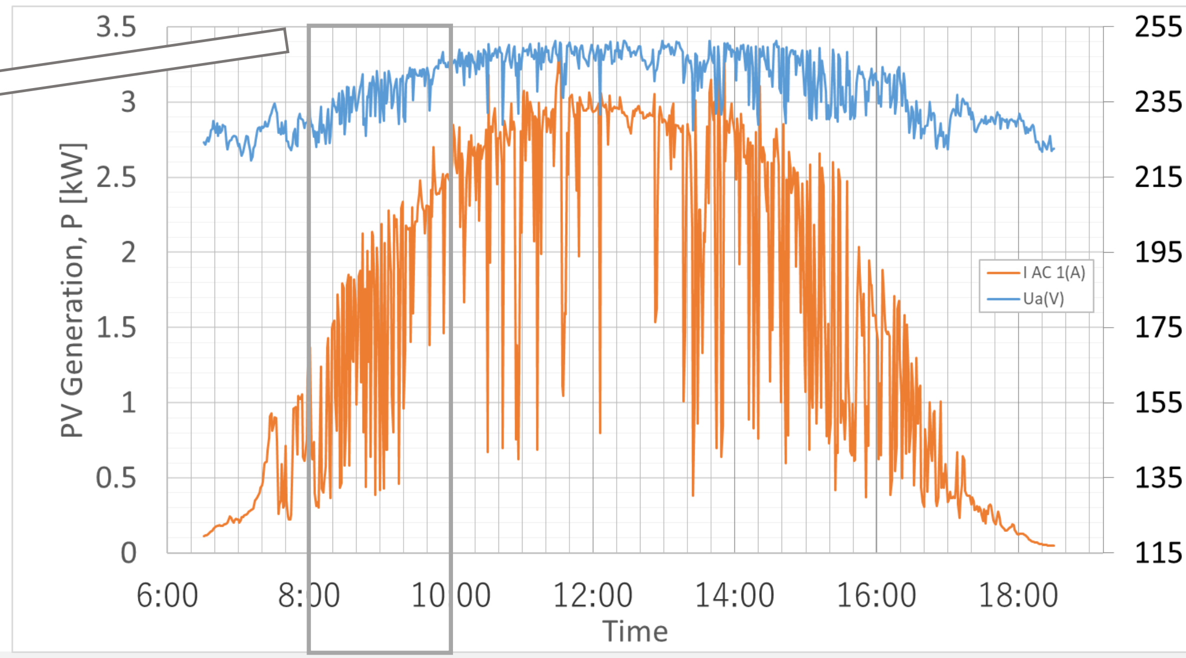
7. Answer whether the following is Y(correct) or N(wrong) regarding the figure showing the voltage and power output by a solar PV generator.
   - ➢ The voltage decreases according to the output power increase in general.

     Circle Y or N

8. ➢ The voltage fluctuated to less than half the maximum values within several minutes.

   Circle Y or N





Examination No. in WG3-2

<Solar PV>

9. Answer whether the following is Y(correct) or N(wrong).
   - The solar PV power generator of 10 kW can charge around 240 kWh in a day (24 hours) if the weather conditions are sufficient.

     Circle Y or N

10. Answer whether the following is Y(correct) or N(wrong), regarding the solar PV generator having the time coefficient dependency of the right table.
    - The power generation is more than 5 kW at 8:00, if the power generation is 10 kW at noon.

      Circle Y or N

Time	Coefficient of generation
7:00	0.07
8:00	0.33
9:00	0.67
10:00	0.83
11:00	0.95
12:00	1.00
13:00	0.97
14:00	0.93
15:00	0.77
16:00	0.50
17:00	0.20
18:00	0.05

Examination No. in WG3-2

<Solar PV>

11. Circle the correct number of the followings, in the conditions of a solar PV power generator of 4.8 kW PV panel and 5 kVA PCS.
    ① The maximum output is 4.5 kW, if the power factor is 1.
    ② The maximum output is 4.8 kW, if the power factor is 1.
    ③ The maximum output is 5 kW, if the power factor is 1.

12. Circle the correct number of the followings, in the conditions of a solar PV power generator of 4.8 kW PV panel and 5 kVA PCS.
    ① The maximum output is 4.5 kW, if the power factor is 0.9.
    ② The maximum output is 4.8 kW, if the power factor is 0.9.
    ③ The maximum output is 5 kW, if the power factor is 0.9.

Examination No. in WG3-2

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<Solar PV>

13. Circle the correct number of the followings.

① Power generation of the solar PV generator depends on the longitude of its location but does not depend on the latitude of its location.

② Power generation of the solar PV generator depends on both the longitude and the latitude of its location.

③ Power generation of the solar PV generator depends on the longitude of its location but does not depend on the latitude of its location.

<BESS>

14. Answer whether the following is Y(correct) or N(wrong).

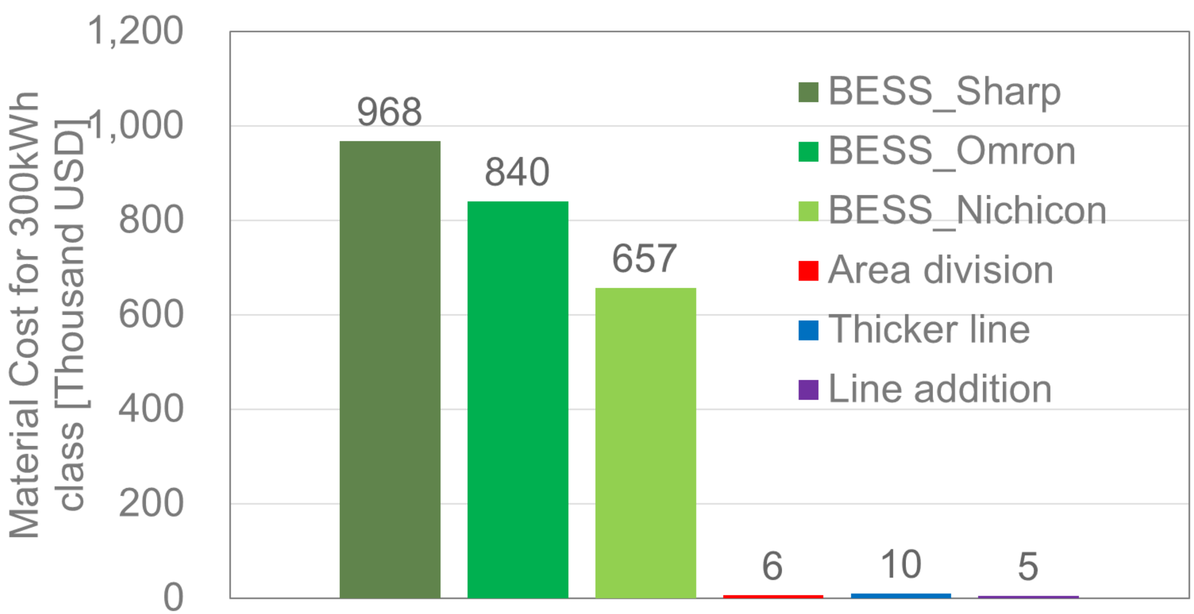
➢ Charging of 1 kW BESS is similar to the consumption of 1 kW customer as load.

Circle Y or N

<BESS>

15. Answer whether the following is Y(correct) or N(wrong) regarding the figure showing the material cost for 300 kWh class.
   - ➢ The cheapest material cost is line addition in the given conditions.

Circle Y or N

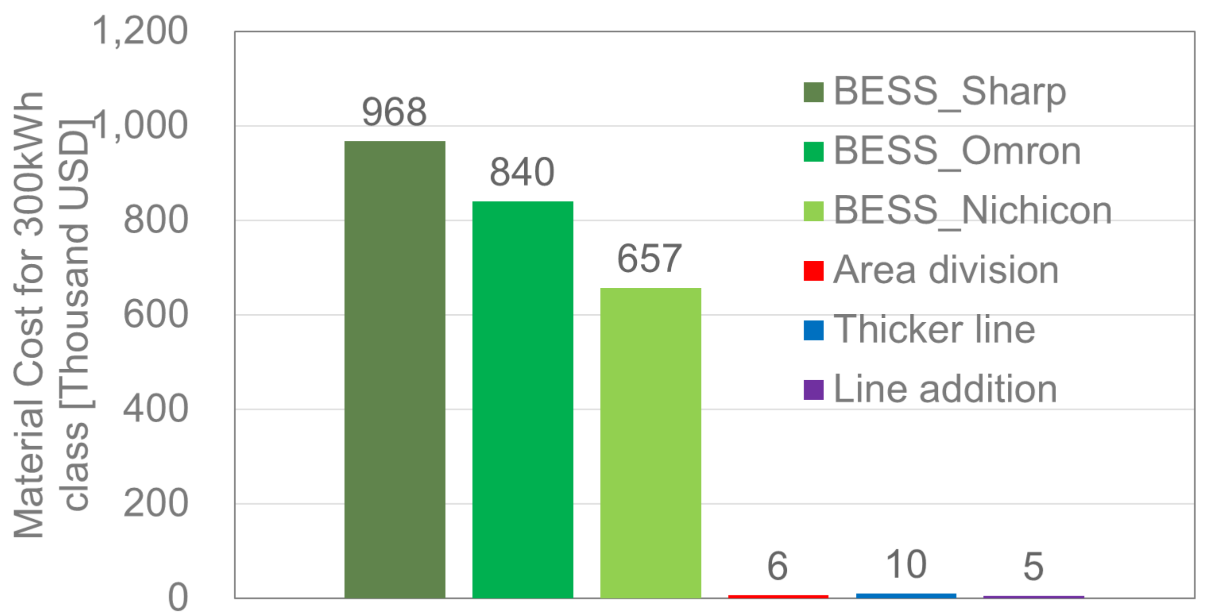


Examination No. in WG3-2

<BESS>

16. Answer whether the following is Y(correct) or N(wrong) regarding the figure showing the material cost for 300 kWh class.
    - ➢ The BESS cost can be cheaper than conventional countermeasures such as thicker line replacement, if it is supposed the BESS cost get down to one tenth (1/10) in the future.

Circle Y or N



Examination No. in WG3-2

<Grid interconnection>

17. Answer whether the following is Y(correct) or N(wrong).
    - A protection relay is necessary for the solar PV generator to interconnect it to a MV distribution grid, but a protection relay is not necessary for the solar PV generator to interconnect it to a LV distribution grid.

Circle Y or N

18. Answer whether the following is Y(correct) or N(wrong).
    - Interconnected power equipment can be damaged, if a distribution line is reclosed to a isolated live (operating) line in the asynchronous conditions.

Circle Y or N

19. Answer whether the following is Y(correct) or N(wrong).
    - A protection device such as a breaker is not necessary, if there is an inverter in solar PV generator.

Circle Y or N

Examination No. in WG3-2

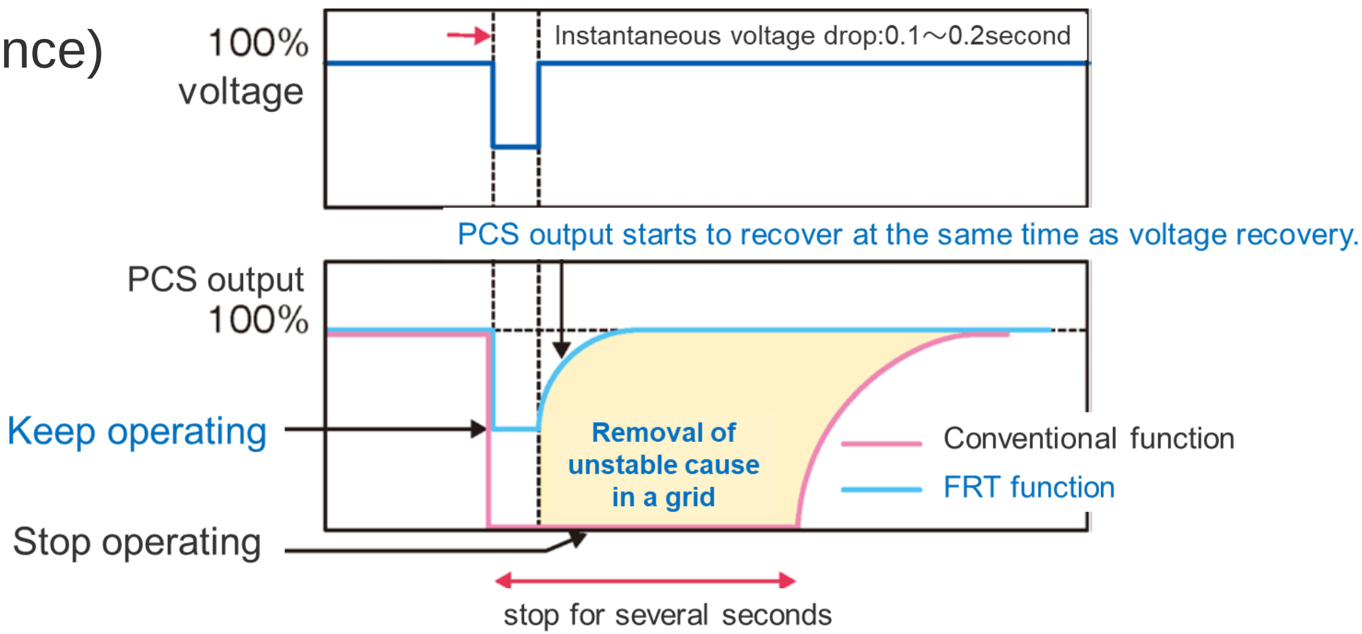
<Grid interconnection>

20. Answer whether the following is Y(correct) or N(wrong).

➢ FRT (Fault Ride Through) is a function that maintains the operation of a PCS even in the event of an instantaneous voltage drop or an instantaneous power outage due to an accident in the power grid.

Circle Y or N

(for a reference)



Examination No. in WG3-2

<VPP>

21. Answer whether the following is Y(correct) or N(wrong).

- A virtual power plant (VPP) is a system that utilizes ICT to integrate and control multiple distributed energy resources in a region as if they were a single power plant, and to adjust the balance of power supply and demand.

Circle Y or N