Presentation Materials of second Workshop

The Smart Meter

The Smart Meter

16th July 2012
Tokyo Electric Power Company, Inc.

1

Contents

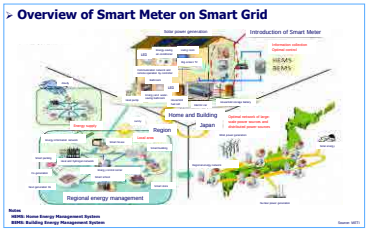
2

I. What's Smart Meter in Japan?

3

Smart Grid and Smart Meter

➢ **Overview of Smart Meter on Smart Grid**



Notes:
HEMS: Home Energy Management System
BEMS: Building Energy Management System

Source: METI

4

Need for Smart Meter on Smart Grid

➢ **A key component of Smart Grid**

✓ **Digital type meter**
Semi-automated digital measurement and meter reading of power data
=Manual intervention in meter reading

✓ **Smart Meter**
Two-way communication in addition to the functions of digital type meter
→ · No manual intervention in meter reading
· Automatically measurement
· Possible to measure and transmit data every short time

Source: METI

5

Evolution of watt-hour meter in Japan

1952 ▪▪▪▪▪▪▪▪▪▪ 1990 ▪▪▪▪▪▪▪▪▪ The present

Analog type meter	Digital type meter	Smart meter
Mechanical measurement (read by person)	Electronic measurement (Through person)	Electronic measurement (read by equipment)
Every 1 month	Every 1 month	Every 30 minutes, etc.
	One-way communication	Two-way communication

6

Introduction background of Smart Meter

➢ **Japan**

✓ Introduction expansion of renewable energy such as large amounts of interconnections with solar power generation system
↓
✓ Occurrence of bad influence on the system stability, etc.
✓ Occurrence of surplus power
↓
✓ Means for two-way communications of control information in power system

★ **Introduction of Smart Meter**

Source: METI

7

Introduction background of Smart Meter

➢ **Japan**

✓ Power supply crunch after great earthquake disaster in eastern Japan on March 11, 2011
↓
✓ Heightened awareness of energy saving on customer side
✓ Power system reform
↓
✓ Demand response

★ **Introduction of Smart Meter**

Source: METI

8

Concept of Smart Meter

➢ **Smart Meter in the narrow sense**
Meter with minimum functions of remote automatic meter reading, remote opening and closing, collection and transmission of measurement data

➢ **Smart Meter in the broad sense**
Meter with visualization of the information such as energy consumption for energy saving and energy management function, to introduce renewable energy such as large amounts of interconnections with solar power generation system and build a flexible system for electricity charges such as time of use in the future, in addition to functions of meter in the narrow sense

Source: METI

9

Difference between AMR,AMM,SM,or AMI

✓ **AMR: Automated Meter Reading**
Remote meter reading by one-way communication

✓ **AMM: Automated Meter Management**
Remote opening and closing Two-way communication, in addition to the functions of AMR

✓ **Smart Meter**
Interval metering and information·data storage, in addition to the functions of AMR and AMM

✓ **AMI: Advanced Metering Infrastructure**
Whole system of information collection and management, including communication from power company side and communication network such as HAN*, in addition to the functions of SM

* HAN: Home Area Network

Source: METI

10

Functions of Smart Meter required in Japan

➢ **Functions of Smart Meter required at present**

✓ **Time axis of meter introduction**
Technological development cycle of meter, etc.

✓ **Overseas cases**
Introduction of meter in Europe: Emphasis on functions such as remote meter reading by two-way communication

✓ **Present situation in Japan**
Increase in costs (cost-benefit), Needs of customer-side for apparatus control, Introduction amount of solar power generation, etc.

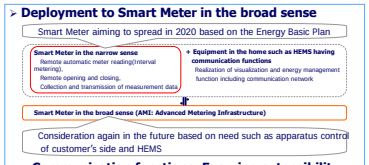
★ **Smart Meter in the narrow sense**

Source: METI

11

Extensibility of Smart Meter function

➢ **Deployment to Smart Meter in the broad sense**



➢ **Communication functions: Ensuring extensibility of information network**
✓ An increase in the number of Smart Meter
✓ An increase in the number of communication amount and measuring time of Smart Meter itself

Source: METI

12

Effect expected with introduction of Smart Meter

➢ **Merit of customer's side**

Application example of information using such as electricity	Expected merit
Addition of remote automatic meter reading and remote opening and closing function	Monitoring of load condition and immediate response of power company during outage
Visualization of usage information such as electricity and charge information, Provision of energy-saving diagnostic services, etc.	Energy and CO_2-saving, Effect of household saving
Optimal apparatus control by HEMS introduction, setting and using of segmentalized charge menu	Further energy and CO_2-saving, Effect of household saving
Centralized grasp and management as energy information added to usage information such as gas	Provision of comprehensive energy and CO_2-saving services
Application of detailed electricity usage information as lifestyle of customer	Provision of watching and application to nursing service for elderly people

Source: METI

13

Effect expected with introduction of Smart Meter

➢ **Merit of electric power companies, etc.**

Application example of information using such as electricity	Expected merit
Addition of remote automatic meter reading and remote opening and closing function	Operational efficiency of local services, etc.
Visualization of usage information such as electricity and charge information	Raising awareness of customers for energy saving, improvement of customer satisfaction
Application to consideration of electricity charge menu by the data of supply and demand patterns including renewable energy	Consideration of way of electricity charge for efficient use of energy, load balancing by induction of demand
Grasp of detailed usage of distribution facilities such as transformers, etc.	Efficient formation of facilities according to actual Use Condition of distribution facilities

Source: METI

14

II. Activities related to Smart Meter of TEPCO

15

Overview of TEPCO's Smart Meter

Smart Meter
- Electronic measurement
- Every 30 minutes, etc. (Interval metering)
- Two-way communication (between Meter and Company)
- Remote automatic meter reading
- Remote opening and closing function
- Collection and transmission of measurement data

- Have introduced experimentally to approximately 1,200 households in model areas of Tokyo from the second half of FY 2010.
- Experimenting demonstration of the communication function, etc.

16

Demonstration experiment for Smart Meter expansion of TEPCO

➢ **Overview of demonstration experiment**

Item	Technical verification	Operational verification
Implementation period	Introduction start from the second half of FY ☒☐	Introduction start from the second half of FY ☒☐
Implementation outline	Demonstration experiment of functions of communication, etc.	Demonstration experiment of business operation on automated meter reading in the entire office ・Remote meter reading, etc.
Introduction number	House: about ☒☐ households Mansion: about ☒☐ households	All customers in the district of one service office: about ☒ thousand households
Verification content (Evaluation criteria)	Transmission quality and connection quality of communication	Verification of effect on improving efficiency of business operation

17

Major activities of TEPCO

➢ **Measures to Peak Shift**
Considering the menu of electricity charges for control of peak demand

➢ **Improving efficiency of business operation**
Considering flow and verification methods of business operation for realization of new business focusing on no visit

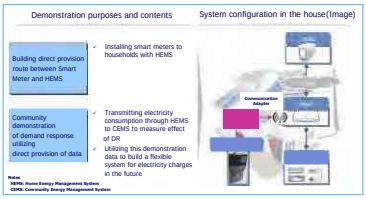
➢ **Cost reduction of Smart Meter**
Reducing procurement costs by optimizing specifications of Smart Meter

➢ **Demonstration of direct provision of measurement data**
Scheduled for realization of provision of measurement data (30 minutes value) directly from Smart Meter to HEMS in Yokohama Smart City Project (YSCP)

18

Activities related to Smart Meter in Yokohama Smart City Project (YSCP)

➢ **Provision of measurement data directly from Smart Meter to HEMS (Image)**



19

III. Introduction situation of Smart Meter in the world

20

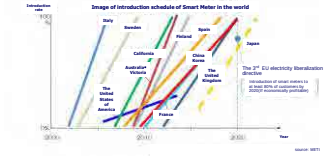
Situation related to Smart Meter in each country

➢ **Overview of a major case in each country**

21

Introduction Situation and plan of Smart Meter in the world

- In the countries and states decided or mandated to introduce Smart Meters on a large scale, the introduction of almost all the meters are expected to be completed in the 2010s.
- In Japan, in the Basic Energy Plan which was revised in June, "Fully considering cost-effectiveness, etc., we aim the introduction of smart meters to all consumers in principle as early as possible of the 2020s".



22

Introduction background of Smart Meter

➢ **The United States of America**

- ✓ Occurrence of large-scale outage (August 2003)
- ✓ Increase in demand
  - ✓ Instability of supply reliability
  - ✓ Demand response (Measures to control demand)
- ✓ Environmental Limitation, etc.
  - ✓ Difficult situation of new power generation installation

★ **Introduction of Smart Meter** ×

23

Introduction background of Smart Meter

➢ **Europe**

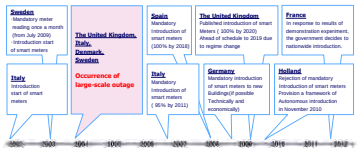
- ✓ Power theft prevention
- ✓ Occurrence of outages in many parts of Europe (2003)
- ✓ Introduction expansion of renewable energy such as large amounts of interconnections with wind power generation system
- ✓ Remote meter reading, Grasp of system information

★ **Introduction of Smart Meter**

24

Introduction progress of Smart Meter in EU major countries

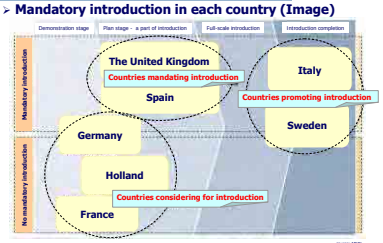
➢ **Outline in each country**



25

Deployment status of Smart Meter in EU major countries

➢ **Mandatory introduction in each country (Image)**



26

Introduction situation of Smart Meter in Asia

➢ **Introduction Progress in each country**

Country name	Smart meter number	All meter number	Outline
China	63,000,000	385,000,000	・Implementing large-scale introduction in accordance with smart grid plan of government ・Introducing 58.5 million smart meters by September 2011 ・Scheduled for introduction 230 million smart meters by 2015
Korea	3,010,000	22,217,471	・Published "National road map of smart grid" in January 2010 ・Building infrastructure of smart meter and two-way communication system for all customers by 2020
India	225,000	144,000,000	・Planned introduction of smart meters as a part of R-APDRP expanded to reduce distribution loss. ・Expected to be introduced around IT companies
Taiwan	100,000	12,387,370	・Published the start of AMI project in 2010 ・Planed to change the meters of all of 12 million housing customers. to smart meters
Thailand	5,000	18,352,498	・Planned by PEA to introduce 3 million smart meters by 2016, 15 million ones by 2021
Singapore	-	-	・Implementing demonstration experiment for introduction of smart meters
Philippines	7,000	15,600,000	・Ditto

Source: METI
Smart Meter number : Introduction situation of AMI (Projects' until 2010)

27

Overseas meter market, manufacturer trends

- Smart meter of the top manufacturers in global market share has been adopted in each country in the world.
- Compared with about 34% world market share of top three manufacturers (Itron/Actaris, Landis+Gyr, Elster) in the world, Japanese market share is about 1.8%.
- Manufacturers in China and India is expanding from the domestic market, their share are higher in the background a huge domestic market.

Meter manufacturer share in the world

The Japan market value (reference) is the ratio of the domestic manufacturing number for the world's annual production number.

<Overseas meter trends >
- The number of installed meter in the world (including mechanical type) is about 1.7 billion, annual production number is about 130 million ($ 5.0 billion).
- In the background such as replacement demand in the countries and states decided to introduce smart meters on a large scale, further expansion of the meter market in the future is expected.

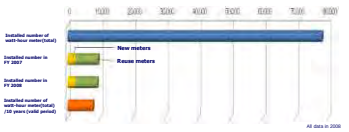
All data in 2009
source: METI

28

Situation of watt-hour meter in Japan

- Japan market scale is about 30 billion yen, compared with about $ 5.0 billion world market. (Production amount is 30.5 billion yen, including export amount is 100 million yen)
- Annual installed number is about 9.0 million, including about 1.9 million new meters. The rest are the existing reuse meters to be collected and repaired.
- Reuse of mechanical-type meters account for the majority and the annual new demand is about 20% of the annual installed number. Production amount per manufacturer is less than overseas manufacturer's. For example, in case five companies supply the smart meters for all meters in Japan(number of contracts: about 80 million, replacement in 10 years), annual supply amount per manufacturer is 1.6 million. However, if the meter of each power company is different, production scale per model will be reduced.

Installed number of watt-hour meter and annual installed number in Japan unit : 1 thousand number



All data in 2008
source: METI

29

Situation of watt-hour meter in Japan

Installed number of watt-hour meter and annual installed number in Japan

unit : 1 thousand number

Power company	Installed number of watt-hour meter (total) (A)	Annual installed number				(B)/10 years (valid period)
		2007		2008		
		Installed number	New meters	Installed number	New meters	
Hokkaido	3,636	412	109	404	94	364
Tohoku	6,723	760	217	721	190	672
Tokyo	27,189	3,038	662	2,859	663	2,719
Chubu	9,428	1,080	178	1,065	167	943
Hokuriku	1,805	215	55	211	54	181
Kansai	12,636	1,623	327	1,585	343	1,264
Chugoku	4,927	659	119	611	126	493
Shikoku	2,730	307	45	329	50	273
Kyusyu	8,178	836	175	824	175	818
Okinawa	800	93	23	98	28	80
Total	78,052	9,024	1,909	8,706	1,890	7,805

All data in 2008
source: METI

Introduction of In-house Training of Tokyo Electric Power Company

Introduction of In-house Training of Tokyo Electric Power Company

July 2012

Tokyo Electric Power Company, Inc.

1. Management principle and management guidelines, and Fundamental principles and system
2. Points of concern in designing and conducting training
3. Introduction of New Employees training and Grade system
4. Incentive system (Introduction of Front-line Workplaces Activities in TEPCO)

Management principle and management guidelines

Management Vision 2010

◆Group Management Principle◆

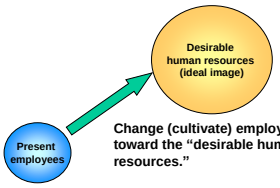
Contribute to the realization of affluent living and pleasant environment by offering optimal energy services

◆Group management guidelines◆

Management Guideline No.1	Management Guideline No.2	Management Guideline No.3
"Win the Trust of Society"	"Survive the Struggle in Competition"	"Foster People and Technology"
Eligibility to participate in the competitive markets is the "trust" that society places in us.	Nothing makes TEPCO Group happier than customer "satisfaction".	"People and technologies" open up the future of our Group.

What is human resources development?

Human resources development means to change employees toward the "desirable human resources."



Review

Changing of Capabilities to be required

Capabilities to be required for technical engineer/technician is changing

[Old requirement]	[New requirement]
・be amenable to discipline	・ability to take action even at contingency
・orderly mind	・spirit of challenge
・steady thinking	・zero-based thinking
・conservative mind	・creative mind

Fundamental principles of human resource development

Main method of Training for the technical engineer/technician is on the job training

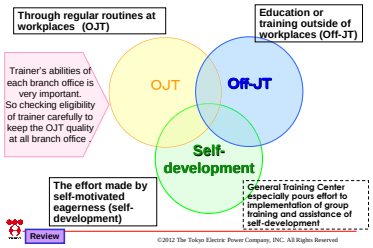
O Fundamental principles

- ・Job rotation
- ・On the job training (OJT)
- ・Group training — Complementary method

O Major training schemes

- ・Group training
- ・Supporting self-development

Human resources development methods



Review

1. Management principle and management guidelines, and Fundamental principles and system
2. Points of concern in designing and conducting training
3. Introduction of New Employees training and Grade system
4. Incentive system (Introduction of Front-line Workplaces Activities in TEPCO)

Basic idea and structure of training - changes in management environment -

- Impact on the style of organization, human resources and job

Organi-zation	Swift decision-making by flattering corporate structure. "Customer service" and "construction, maintenance and operation of facility" in an integrated manner
Human resources	The system of pay and benefits was reviewed to make it more merit-/ability- based.
Practice	Business operation structure best suited for electricity business was reestablished. Intensive enhancement and effective utilization of facility maintenance.

Basic idea and system of training - challenges and direction of measures -

- Cultivation of human resources based on OJT should be maintained while the system focusing on the followings requires development

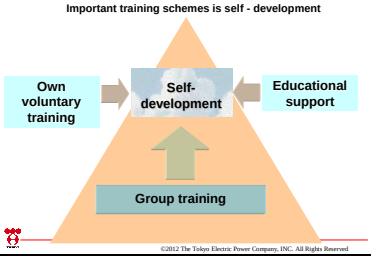
Improvement of front-line technologies and skills as well as ability to discover and solve issues

Enhancement of management ability among management-level staffs

Leadership for innovation

Training schemes for human resource development

Important training schemes is self - development



4-[2]. Points of concern in designing and conducting training

◆Tasks ◆Points of concern

Tasks	Points of concern	
Designing of training	Company-wide recognition of challenges Review of training system * Selection of instructors *Selection of text books	Utilization of external resources (Instructors in particular)
Conducting of training (Operation)	*Awareness of purpose and significance *Ex ante assignment *Assistance to practice at a workplace (including ex post assignment)	Quality maintenance Effect measurement

Selection of training instructor

O In principle, instructors who is commensurate with a theme should be selected from company members

- Such instructors are fostered when needed

O External instructors should be invited when their knowledge gained outside of TEPCO is expected to bring about greater effects

- e.g. Educational consultants, professors and others

O Instructors are carefully selected based on the assessment of the following points

- Purpose for training and eligibility for prospective result
- Specialty and instruction skill, etc.

- Evaluation made by secretariat, or based on questionnaire from training participants

Review

Important parts of training implementation

○ Contents are set from the perspective of followings upon the consultation with training instructors

1. Ex ante assignment
   - should inspire motivation about participating in training
   - Set one's own agenda, upon consultation with boss, before taking a training
2. Educational materials
   - should supplement content of a lecture
   - could be what instructors use during a lecture
   - Requires to be well organized, purposeful and easy to understand while including up-to-the-minute details
3. Ex post assignment
   - should be associated with what was learned from a training and practical skills
   - Take action toward problem-solving after receiving a training
   - Follow-up provided by the center

Quality maintenance and effect measurement of trainings

[Quality]

- O Discovering quality and eligibility of an instructor as well as content and skill level provided by the instructor
- O Observation on a degree of response from participants
- O Provision of feedback composed of obtained results to instructors

- To maintain and improve training, every training undergoes quality control and effect measurement

[Effect measurement]

- O Evaluation of training based on questionnaire filled out by participants and their boss
  - Benefits, earned throughout trainings, of practicing at a workplace
  - Practicality in terms of action
  - Benefits of each program
- O Confirmation on implementation status of practical skills executed at workplaces (WPL: Work Place Learning)

- Confirm whether participants put what they learned from trainings in practice at their workplaces

1. Management principle and management guidelines, and Fundamental principles and system
2. Points of concern in designing and conducting training
3. Introduction of New Employees training and Grade system
4. Incentive system (Introduction of Front-line Workplaces Activities in TEPCO)

Annual Training Schedule for New Employees

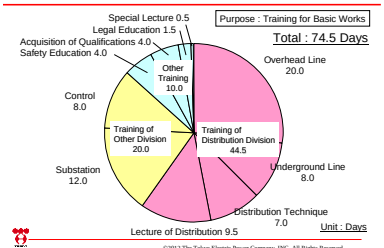
	First Half-Year 4 5 6 7 8 9	Second Half-Year 10 11 12 1 2 3
OJT	Branch Office • Education at the time of employment • Legal education • Basic manner training	Service Center • OJT • Collective Training in the branch office
GT*	Training Center (4 months) • Collective training of first half-year • For all new employees of technical division • Basic training	Training Center (5 months) • Collective training of second half-year • For new employees of distribution division • Advanced training

* Group training

Training Composition of First Half-Year

Purpose : Training for Basic Works

Total : 74.5 Days

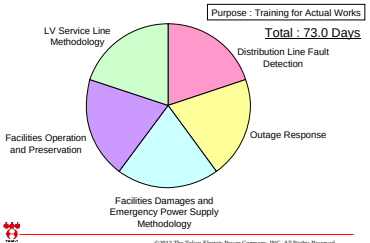


Unit : Days

Training Composition of Second Half-Year

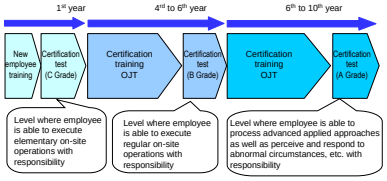
Purpose : Training for Actual Works

Total : 73.0 Days



Grade system

The level of Operational Technique/Skills Certification System



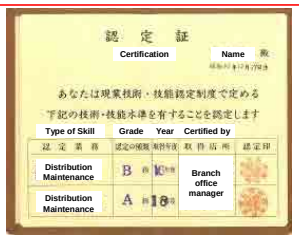
Level where employee is able to execute elementary on-site operations with responsibility

Level where employee is able to execute regular on-site operations with responsibility

Level where employee is able to process advanced applied approaches as well as perceive and respond to abnormal circumstances, etc. with responsibility

- Chef worker / Supervisor need to have A Grade
- Emergency maintenance team leader need to have A Grade

Grade Certification



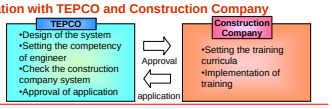
Relation and Level of Construction Company

Type of Technique/Skills

- Construction Technique/Skills (1st , 2nd, 3rd Grade)
  (Overhead line course, Undergrad cable course)
- Construction management Technique/Skills

Level of Technique/Skills

Relation with TEPCO and Construction Company



1. Management principle and management guidelines, and Fundamental principles and system
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4. **Incentive system (Introduction of Front-line Workplaces Activities in TEPCO)**

Qualification Reward System

- TEPCO supports staffs to pass Public Qualification Tests and reward those who passed the tests with financial incentives

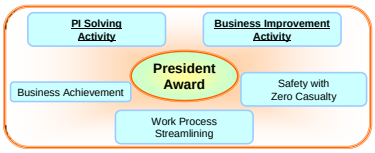
Public Qualification Test	Financial Incentive
Qualified Electrical Chief Engineer (1st grade) National Judicial Examination (Lawyer) Certified Public Accountant Doctor's Degree (Ph. D)	Nu. 214,000
Patent Attorney Processional Engineer	Nu. 142,000
First-class Architect Certified Tax Accountant	Nu. 71,000

*1.4 JPY /BTN

Incentive system (Introduction of Front-line Workplaces Activities in TEPCO)

President Award System

- TEPCO incorporate "Business Improvement Activity" and "PI solving activity" into President Award System



- Remarkable Cases can be rewarded as the President Award
- Maximum Reward Incentive is 357,000 BTN

New activities

We are implementing activities toward the enforcement of maintenance and succession of techniques and skills.

- Increase in opportunities to directly use techniques and skills
- Enhanced desire to master techniques and skills

1. **Establishment of Certified Skill S Grade**
2. **Establishment of professional technical teams**
3. **Holding of a company-wide skills competition**

Review

Establishment of S Grade

◇Established as a grade upper than A Grade

Human resources capable of responsibly pursuing technical succession and human resources development (with a high technical capability and leadership ability) will be certified through the following tests.

- **Test on sector-specific professional techniques**
- **Test on leader competence**

A certificate will be granted by the president.

The certified personnel will be also permitted to wear a special design uniform.

Establishment of professional technical teams

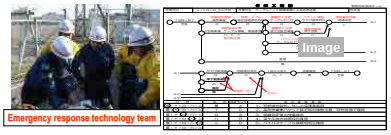
Professional technical teams will be established chiefly under the direct control of the head office to maintain and strengthen techniques/skills.

<Example of professional teams>

Sector		Professional technical team	Major practical activity
Transmission	Hydro power generation	Water turbine generator engineering team	・Designing, construction, test of water turbine repair works
	Overhead transmission	Steel tower maintenance technology team	・Basic displacement, variation diagnosis, structural component deterioration diagnosis, steel tower strength determination, designing of optimum repair/reform
	Power transformation	Protection control engineering team	・Designing, construction, test of switchboards ・Business improvement/efforts on problem solving
	Power distribution	Emergency response technology team	・Repeated training specialized in improvement of practical technologies from judgment to treatment of facilities incidents
		Maintenance technology team	・Practice of measurement/diagnosis technologies accompanied by advanced evaluation
		Distribution equipment engineering team	・Investigation and analysis of faulty equipment

5 to 10 persons/team

Training of professional technical teams



Emergency response technology team

- Harsh conditions not likely to occur normally are developed intentionally.
- The team members will repeat competitive training over prepared issues.
- The team members will acquire problem-solving abilities by addressing the problems through practice, scientific analysis and thorough discussion rather than instinct, experience, and courage.

Review

Company-wide technique and skills competition (president cup)

Held with the aim of improving the desire to acquire techniques and skills, creating the corporate culture respecting techniques and skills, and vitalizing workplaces.

- Evaluated with "safety," "quality," and "efficiency" as common criteria
- The actual number of participants in the competition was expanded by holding elimination contests.
- The competition functions as a setting to spread the possessed techniques throughout the company.

Power distribution maintenance; Emergency power transmission

Overhead transmission line; Jumper operation

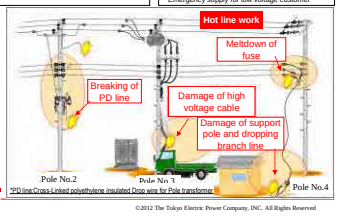
Power transformation; Pre-service inspection of mobile switch

Theme of president cup

Time limit : 75 min.

1. Target
・Recovery work of damaged line and emergency electric power supply

2. Activities
・Recovery work of damaged line
・Emergency supply for high voltage customer
・Emergency supply for low voltage customer



Effects of competition

- Engineering capabilities were enhanced through the training toward the competition.
  - Elimination contests were held at some branch offices. (Effective in further expanding the actual number of participants.)
- Consciousness of participants was enhanced by the observation of the management.
- The competition functions as a setting to spread the possessed techniques of TEPCO throughout the company.
  - Deepened technical exchanges with other branches and other sectors

Namesame
Kadrinche

Presentation Materials of third Workshop

Protection Relay and Relay Coordination

Protection Relay and Relay Coordination

February 2013

Tokyo Electric Power Company, Inc.

1. Outline of Protection Relay and Coordination
2. Outline of Protection Relay and Coordination in the TEPCO System
3. Protection Relay and Coordination in the TEPCO 66kV System
4. Protection Relay and Coordination in the TEPCO 6.6kV System
5. Preferred Specifications
6. Technical Trends

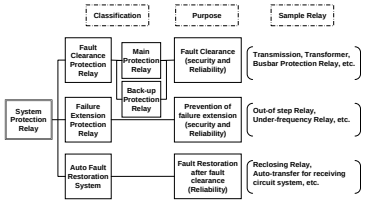
Purpose of Protection Relay

[purpose]

Isolating the faulty part from the healthty system so that fault does not spread over the other points

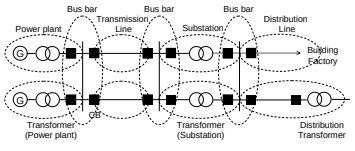
- ✓ **Security :**
  - ➢ Damage prevention of the power facility
  - ➢ Public safety
- ✓ **Reliability :**
  - ➢ Minimization of the outage area
  - ➢ Stabilization of the power system

Classification of Protection Relay



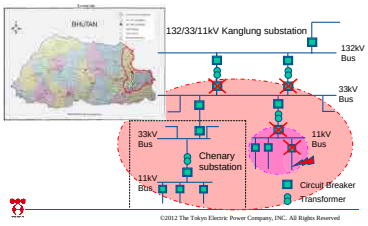
Covered area of Protection Relay

Each Protection Relay has the protection area for minimizing the outage area and reliability of the power system



G : Generator
CB: Circuit Breaker

Purpose of Protection Relay

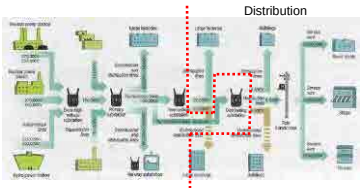


1. Outline of Protection Relay and Coordination
2. Outline of Protection Relay and Coordination in the TEPCO System
3. Protection Relay and Coordination in the TEPCO 66kV System
4. Protection Relay and Coordination in the TEPCO 6.6kV System
5. Preferred Specifications
6. Technical Trends

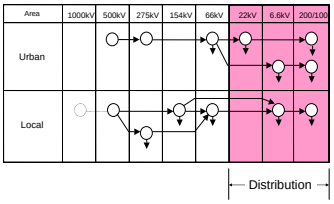
[Review] Outline of TEPCO Power System

500kV UG
275kV UG
500kV OH
275kV OH

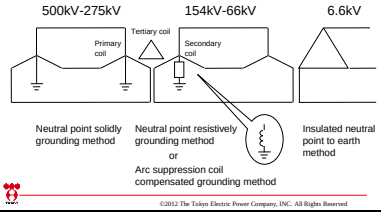
[Review] Outline of TEPCO Power System



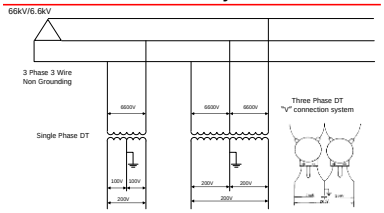
[Review] TEPCO's Voltage Leve



[Review] Transmission System



[Review] Distribution System



Guiding principle of Protection Relay Coordination

[Guiding principle]

- ➢ It is necessary to clarify the purpose of installing protection relay equipment , the covered area of protection relay and the type of accident which the protection relay can operate with.
- ➢ It is necessary to coordinate the other relay for reliable operation and prevention of improper operation.
- ➢ It is necessary to calculate the setting value in consideration of real system configuration and manner of operation.

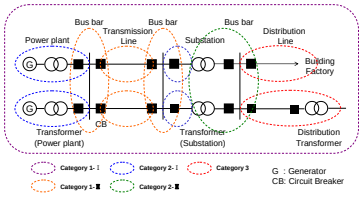
[Necessary information for Protection Relay Coordination]

- ➢ System configuration, Impedance, Power flow, Zero-phase circulating current, Steady state stability, Transient stability, Short circuit capacity (current) etc.
- ➢ Protection relaying scheme, Characteristic of existing protection relay
- ➢ Characteristic of current transformer and voltage transformer
- ➢ Break time and make time of circuit breaker
- ➢ Capacity of line conductor, bus bar and power facilities

Category of Protection Relay (TEPCO)

- ✓ **Category 1- Ⅰ**
  Protection relay for whole system protection (Under-Frequency Relay, etc.)
- ✓ **Category 1- Ⅱ**
  Protection relay which is operated by system load dispatching office (500kV line Protection Relay, etc.)
- ✓ **Category 2- Ⅰ**
  Protection relay which is operated by branch office load dispatching station (66kV Line Protection Relay, etc.)
- ✓ **Category 2- Ⅱ**
  Protection relay which is operated by service center control and maintenance office (66/6kV Transmission Protection Relay, etc.)
- ✓ **Category 3**
  Other protection relay (6kV Line Protection Relay, etc.)

Image of Covered area of Protection Relay



G : Generator
CB: Circuit Breaker

Responsible of Implementation of Protection Relay Setting

Category of Protection Relay	Department in charge
Category 1- Ⅰ	Service center control and maintenance office
Category 1- Ⅱ	
Category 2- Ⅰ	
Category 2- Ⅱ	Power plant
Category 3	

Responsible of Operation of Protection Relay Setting

Category of Protection Relay	Department in charge
Category 1- Ⅰ	System load dispatching office
Category 1- Ⅱ	
Category 2- Ⅰ	Branch office load dispatching station
Category 2- Ⅱ	Service center control and maintenance office
Category 3	Service center control and maintenance office Power plant

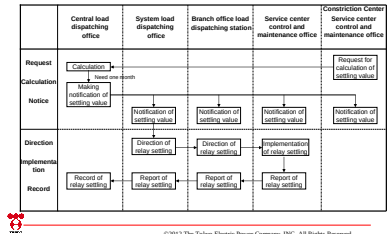
Responsible of Recordkeeping of Protection Relay Setting

Category of Protection Relay	Department in charge
Category 1- Ⅰ	Central load dispatching office
Category 1- Ⅱ	System load dispatching office
Category 2- Ⅰ	Branch office load dispatching station
Category 2- Ⅱ	
Category 3	

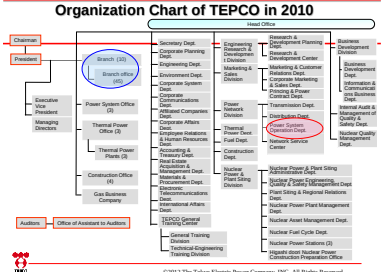
Analysis software for Calculation of Protection Relay Setting

Department	Department in charge
Central and System load dispatching office Branch office load dispatching station	GST:Phase fault analysis Ground fault analysis NTR-Y:Stability analysis FDC:Power flow analysis (*Self - developed software)
Engineering Department Branch Office	GST etc. (*Self - developed software)
Distribution Department	Self - developed software PQQAS (Power Quality Analysis) (*Self - developed software)

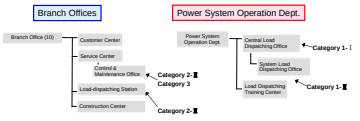
Process of Protection Relay Setting (Category 1- Ⅰ)



Organization Chart of TEPCO in 2010

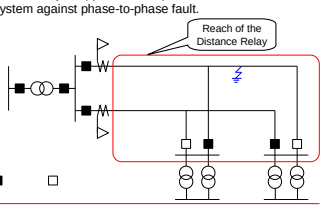


Organization Chart of TEPCO in 2010



Phase-to-Phase Fault Protection for 66kV transmission lines

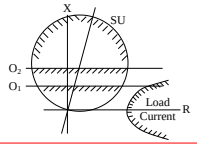
Distance Relay is applied for the protection of the 66kV system against phase-to-phase fault.



Distance Relay Setting

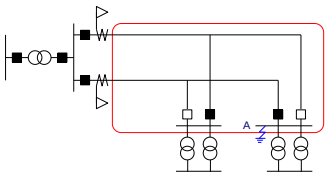
O*i* (Reactance): Correctly detects the distance regardless of arc resistance

SU (MHO): Correctly detects the direction of the fault regardless of load current



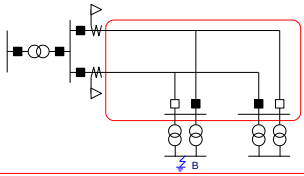
Distance Relay Setting

A fault at the end of the transmission line causes minimum fault current within the reach of the distance relay.

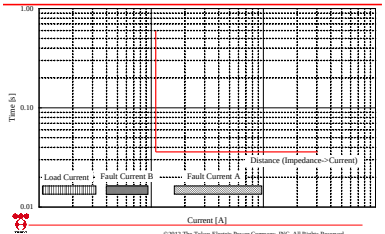


Distance Relay Setting

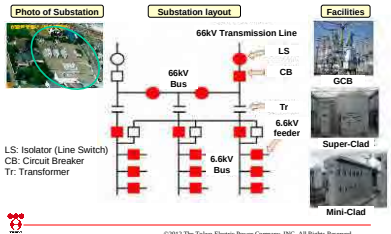
The distance relay shouldn't trip the line by the fault on the secondary side bus of the 66/6.6kV transformer.



Distance Relay Setting



Distribution Substation (66kV/6.6kV) Facilities



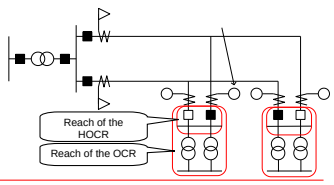
Main Relay Type of Substation (66kV/6.6kV)

Standard Relay Setting in the TEPCO 66kV/6.6kV substation

Relay Name	Relay Type	Purpose	Standard Relay Setting (Sample)
Phase fault relay	Over current relay (OCR) (51L)	Phase fault protection for whole substation	Value: 150% of installed transformer capacity Time:0.6-1.0s
	Over current relay (HOCR) (51H)	Phase fault protection for 66kV system	Value: <150% of maximum short circuit current at transformer secondary winding >50% of minimum short circuit current at 66kV busbar Time: 0.05s
	Over current relay (HOCR) (51T)	Phase fault protection for transformer and 6.6kV system	Value: 160% of rated current Time: 0.6-0.1s
Earth fault relay	Over current relay (OCGR)	Earth fault protection for 66kV system	Value: 30A Time: 0.05-0.0759s
Percentage differential relay	Percentage differential relay (RDfR)	Transformer fault protection	Value: 67% of rated current Percentage differential : 50% Time: instant

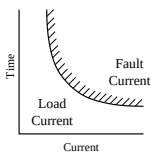
Phase-to-Phase Fault Protection for 66/6.6kV substations

Overcurrent Relay is applied for the protection of the 66/6.6kV substation against phase-to-phase fault.

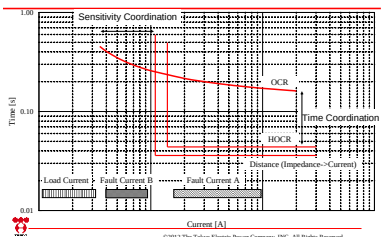


OCR Setting

A setting of OCR has an inverse time characteristic.

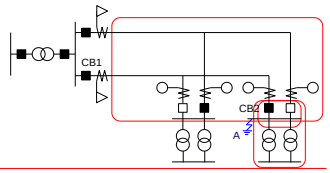


Relay Coordination



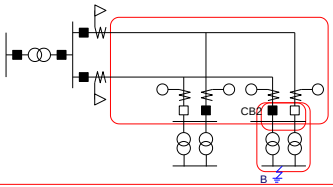
Relay Coordination

Distance relay trips CB1 instantly at the same time as HOCR trips CB2.



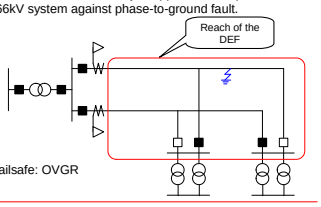
Relay Coordination (Sensitivity Coordination)

For the fault on the secondary side of the 66/6.6kV transformer, OCR trips CB2.



Phase-to-Ground Fault Protection for 66kV transmission lines

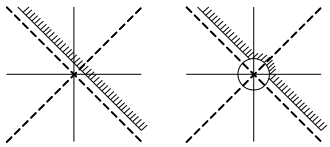
Directional Earth-Fault Relay is applied for the protection of the 66kV system against phase-to-ground fault.



Failsafe: OVGR

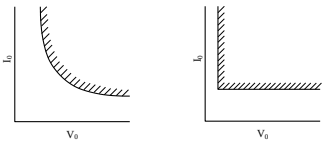
DEF Relay Setting

Phase Characteristics



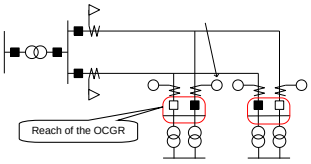
DEF Relay Setting

V_0-I_0 Characteristics



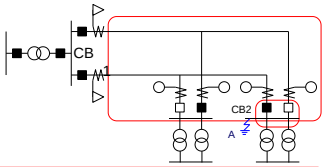
Phase-to-Ground Fault Protection for 66/6.6kV substations

Overcurrent Ground Relay is applied for the protection of the 66/6.6kV substation against phase-to-ground fault.



Relay Coordination (Time Coordination)

OCGR trips CB2 before DEF trips CB1.



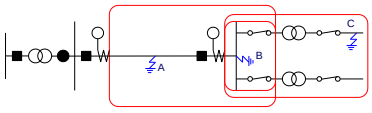
Relay Type of 6.6kV System

Standard Relay Setting in the TEPCO 6.6kV System

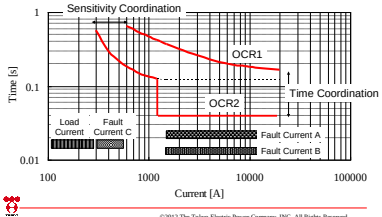
Relay Name	Relay Type	Purpose	Operating duty	Standard Relay Setting (Sample)
Phase fault relay	Over current relay (OCR)	Phase fault protection	Operating at the distribution line end fault (less than 85%)	Value: 150% of maximum allowable current Time: 0.2s
Earth fault directional relay	Earth fault directional relay (DEF)	Earth fault protection	Operating at 30% of earth fault	Value: 200mA Time: 0.9s
Earth fault overvoltage relay	Voltage detecting relay	Voltage detecting (using the part of Earth fault directional relay)	-	Value: 10% of normal voltage Time: 0.9s

Phase-to-Phase Fault Protection for the 6.6kV system

Overcurrent Relay is applied for the protection of the 6.6kV system against phase-to-phase fault.



Relay Coordination

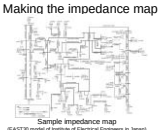


Method of the Relay coordination

1. Making the impedance map of necessary section
2. Calculation of the short circuit current
3. Calculation of the continuous rating current of the CT
4. Calculation of the overcurrent strength of the current transformer (thermal strength, mechanical strength)
5. Setting OCR for incomer feeder (receiving circuit)
6. Setting OCR for main transformer
7. Setting OCR for outgoing feeder
8. Drawing protection coordination curve

Method of the Relay coordination

1. Making the impedance map of necessary section



Sample impedance map (EAST30 model of Institute of Electrical Engineers in Japan)

Sample impedance map for calculation of the short circuit current

2. Calculation of the short circuit current

Method of the Relay coordination

3. Calculation of the continuous rated current of the CT (6.6kV)

Case 1 Using contract demand data

$$I_{N\_contract} = \frac{P_C}{\sqrt{3}\times 6.6\times\cos\phi}\times\alpha$$

$I_{N\_contract}$: continuous rated current of CT [A]
P_C: contract demand [kW]
α : safety margin [1.3-2]
Cosφ : demand power factor [0.8-0.95]

Case 2 Using installed capacity (installed facilities data)

$$I_{N\_facility} = \frac{P_A + P_B}{\sqrt{3}\times 6.6}\times\alpha$$

$I_{N\_facility}$: continuous rated current of CT [A]
P_A: apparent Power of transformer [kVA]
P_B: equivalent capacity of moter [kVA]
α : safety margin [1.3-2]

Case 3 Using overcurrent constant data

$$I_{3LS} \le I_{N\_constant}\times n_x$$

$$I_{N\_constant} \ge \frac{I_{3LS}}{n_x} \quad n_x = \left|\frac{Z_s + Z_t}{Z_t + Z_m}\right| \times n$$

n: rated overcurrent constant
n_x: overcurrent constant of each demand
Z_S: secondary winding impedance [Ω]
Z_T: rated demand impedance [Ω]
Z_m: each demand impedance [Ω]

Method of the Relay coordination

4. Calculation of the overcurrent strength of the current transformer (thermal strength, mechanical strength)

4-1 Thermal strength

$$(I_N\times D)^2\times 1\text{sec} \ge I_S^2\times t$$

$$D \ge \frac{I_S}{I_N}\sqrt{t}$$

I_N: primary rated current of CT [A]
I_S: short circuit current [A]
D: overcurrent strength of the current transformer
t: time of short circuit current [s]

4-2 Mechanical strength

$$I_N\times D\times 2.5 \le I_S\times k$$

$$D \ge \frac{I_S}{I_N}\times\frac{2.5}{k}$$

$$k = \sqrt{2}\left(1+\varepsilon^{-\frac{R}{X}}\right)$$

k: maximum current instantaneous value factor
R: combined resistance
X: combined reactance

Method of the Relay coordination

5. Setting OCR for incomer feeder (receiving circuit)

5-1 Setting OCR (51L)

a. Value setting

$$T \ge I_L = \frac{P}{\sqrt{3}V_n}\times\frac{1}{CT\_ratio}\times(1.5)[A]$$

P: installed transformer capacity [MVA]
I_L: 150% continuous rated current [A]
T: tap value

b. Checking the loop current

Using impedance map

in house standard

c. Time setting

Using in house standard (1.0s)

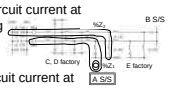
Method of the Relay coordination

5. Setting OCR for incomer feeder (receiving circuit)

5-2 Setting HOCR (51H)

a. Calculation of maximum short circuit current at transformer secondary winding

$$I_{S1} = \frac{P_s\times 100}{\sqrt{3}\times V_n\times\sum\%Z_1}\times\frac{1}{CT\_ratio}[A]$$



b. Calculation of minimum short circuit current at 66kV busbar

$$I_{S2} = \frac{P_s\times 100}{\sqrt{3}\times V_s\times\sum\%Z_2}\times\frac{1}{CT\_ratio}\times\frac{\sqrt{3}}{2}[A]$$

P_S: Base capacity
V_S: Base voltage
%Z_2: Percent impedance

c. Value setting: $I_1\times(1.5)\le T\le I_2\times(0.5)$

in house standard

d. Time setting: Using in house standard (0.05s)

Method of the Relay coordination

6. Setting OCR (51T) for main transformer

a. Calculation of transformer rated current

$$I_T = \frac{P_t}{\sqrt{3}\times V_t}\times\frac{1}{CT\_ratio}[A]$$

P_t: Transformer capacity [MVA]
V_t: Transformer rated voltage

b. Calculation of short circuit current at 6.6kV busbar

$$I_S = \frac{P_s\times 100}{\sqrt{3}\times V_t\times\%Z}\times\frac{1}{CT\_ratio}\times\frac{\sqrt{3}}{2}[A]$$

P_S: Base capacity
V_t: Transformer rated voltage
%Z: Percent impedance

c. Value setting: $I_T\times(1.6)\le T\le I_S\times(0.5)$

d. Time setting: Using in house standard (0.75s)

in house standard

Method of the Relay coordination

7. Setting OCR for outgoing feeder

a. Checking of continues allowable current : I

b. Temporary value setting: $T_T \geq I \times (1.5)$

T_T: Temporary setting value
P_C: Base capacity
V_C: Base voltage
%Z: Percent impedance

c. Calculation of short circuit current at the terminal point of distribution line

$$I_{Si} = \frac{P_c \times 100}{\sqrt{3} \times V_c \times \%Z} \times \frac{1}{CT\_ratio} \times \frac{\sqrt{3}}{2} [A]$$

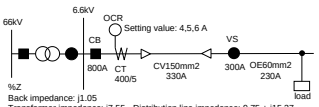
in house standard

d. Checking the short-time allowable current

e. Value setting

d. Time setting: Using in house standard (0.2s)

Sample Relay Setting of Phase fault relay



(a) 150% of maximum allowable current = 230A * 150% * (5/400) = 4.31 (A)
(b) Temporary setting value: 5 A (5 > 4.31)
(c) Check the distribution line end fault
%Z = j1.05 + j7.55 + (9.75 + j15.27) = 9.75 + j23.87 = ((9.75)2 + (23.87)2)-0.5 = 25.78%
Phase fault current (2phase) = (10 * 100) / 25.78 * 1 / (√3 *6.6) * √3 / 2 = 2.94 (kA)
2940 / 400 *100 = 735 (%) > 150(%)
(d) Setting value: 5 A
(d) Setting Time: 0.2s (Standard)

Example of the time coordination

Combination of high-speed relay and time-lag relay

Step	Time setting	Time lag
1	0.2	-
2	0.5	0.3
3	0.8	0.3
4	1.1	0.3

Combination of induction disc type relay

Step	Time setting	Time lag
1	0.2	-
2	0.6	0.4
3	1.0	0.4
4	1.5	0.5

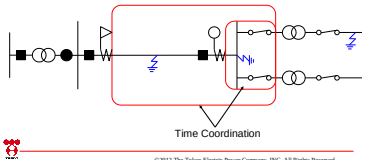
Example of the time coordination

・Incomer feeder OCR: 0.7～0.75 s
・Outgoing feeder OCR: 0.2 s
・Customer OCR: 0.15 s

Phase-to-Ground Fault Protection for the 6.6kV system

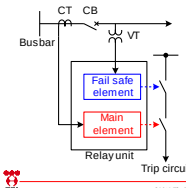
DEF and OCGR is applied for the protection of the 6.6kV system against phase-to-ground fault.

(same as the 66kV system)



Hardware Design

Avoid malfunction cased by single failure mode of hardware



Separate hardware assigned for main relay and fail safe relay elements including input and trip output circuits

Hardware Design

Radio Noise Interference

No maloperation under the following radio noise conditions

- 5W transceivers with 150MHz and 400MHz
- Mobile phone with 900MHz
- Edge of antenna directly touches or becomes close to the relay

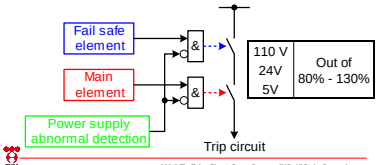
Measures to avoid maloperation

- Shield printed circuit boards
- Lower power source impedance (Thicker pattern)
- Appropriate component layout to minimize circuit length
- Application of appropriate parts such as bypass capacitors for absorbing noise

Hardware Design

DC Supply Fluctuation

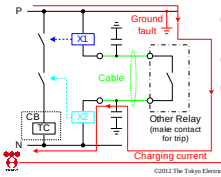
When voltage fluctuation including ON/OFF switching is detected on DC supply circuit, trip circuit shall be blocked



Hardware Design

DC Supply (Ground Fault)

When DC supply circuit touches earth circuit, malfunction shall be prevented

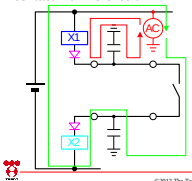


- Dual coil allocation for trip signal receiving circuit from another relay
- Effective in either P or N polarity grounding
- Downgrade of relay sensitivities
  - Voltage: 30- 40V
  - Current: >80mA

Hardware Design

DC Supply (Contact with AC circuit)

Measure to avoid malfunction when AC circuit comes into contact with DC circuit

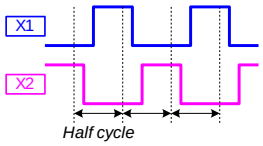


- Insert diodes in series to block simultaneous operation of both auxiliary relays, X1 and X2
- Similar effect against alternating grounding of DC circuit

Hardware Design

DC Supply (Contact with AC circuit)

Take care of coordination between operation and reset times for X1 and X2



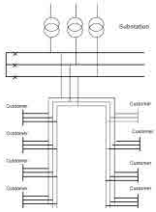
Operation Principles

Static Type (Module Composition) Digital Type

Operation Principles

	Electromagnetic	Static Type	Digital Type
Function	Limited to simple characteristics Limited speed △	Higher sensitivity, more complicated characteristics, and faster speed than electromagnetic type ○	More stable calculation, more complicated characteristics, and faster speed than static type ◎
Reliability	Effect from a change in circuit constant and mechanical condition No automatic monitoring ×	Lowered reliability due to increased electronics parts Automatic monitoring ○	No deterioration with age in calculation error Enhanced automatic monitoring ◎
Maintenance	Not patterned hardware Large-size test set for test input Small inspection interval △	Not patterned hardware Smaller test set, and extended inspection interval compared to electromagnetic type ○	Patterned hardware Smaller test set, and further extended inspection interval compared to static type ◎

New technology in Japan Spot Network System

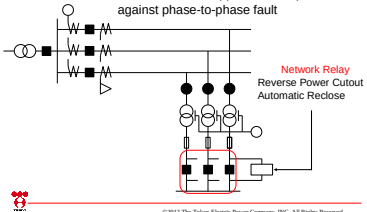


High Reliability

- Each customer is connected to the network through three feeders.
- Loading level of one distribution line is limited within 67% of its capacity, so there is no power outage under N-1 contingency.

New technology in Japan Spot Network System

Protector fuse is applied for the protection against phase-to-phase fault



Namesame
Kadrinche

Presentation Materials of fourth Workshop

Distribution System Planning (Distribution System Planning in TEPCO)

Distribution System Planning in TEPCO (about grid system)

14 May 2013

TOKYO ELECTRIC POWER COMPANY

Today's Contents

1. Outline of TEPCO's distribution
2. Distribution grid System Planning
3. Improvement of System Reliability
   - Shortening of the power outage
4. Improvement of System Reliability
   - Fault Prevention Measures
5. Maintain appropriate Voltage
6. Summary

1. Outline of TEPCO's distribution

TEPCO's voltage criteria

Area	1000kV	500kV	275kV	154kV	66kV	22kV	6.6kV	200/100
Urban		○	○	○	○	○	○	
Local	○			○	○	○		

Distribution division

1. Outline of TEPCO's distribution

Power supply method by the contract demand

Contract demand	Electric supply method	Application
Less than 50 kW	・AC100V 1-phase 2-wire system ・AC100V/200V -phase 3-wire system ・AC200V 3-phase 3-wire system	- Residence - Small factory, office / commercial building
50 - 2,000 kW	・AC6.6kV 3-phase 3-wire ・22kV in high density demand area (Over 500kW)	- Medium size factory, building - Large size shop - Pump station
2,000 - 10,000kW	・AC22kV or 66kV 3-phase 3-wire system	- Large size building and factory - Department store - Pump station - Sewage treatment factory
10,000 - 50,000 kW	・AC 66kV 3-phase wire system	- Large size building and factory - Substation for train
Over 50,000 kW	・AC 154kV 3-phase wire system	- Large size factory - Substation for train

2. Distribution grid System Planning

What is distribution system planning?

Thorough demand trend and grasp of the facilities actual situation and feasibility study

Middle and Long term planning

Stable Power Supply

keep appropriate voltage

Improvement of the investment efficiency

System coherent way of thinking

Supply reliability
Securing of social security

Maintenance operative cooperation with aspects of facilities

Securing of service level

Cooperation with the community

Basic concepts: Effective investment (Reduce total system cost)

2. Distribution grid System Planning

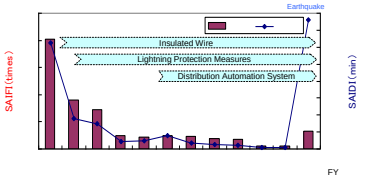
- Stable power supply
  Stable frequency and voltage, suppression harmonics distortion and flicker, continuously power supply etc.
- System Reliability
  decrease or maintain low level SAIFI and SAIDI index
- Maintain appropriate supply voltage (LV)
  follow (national) regulations

- Technical solutions -
✓Distribution system configuration
✓Distribution equipment specification R&D

3. Improvement of System Reliability (Shortening of the power outage)

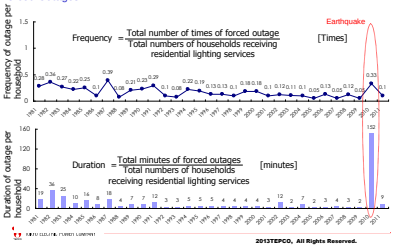
Contribute to Higher Reliability

TEPCO's Historical Trend of SAIDI and SAIFI



3. Improvement of System Reliability (Shortening of the power outage) Reference

Forced Outages

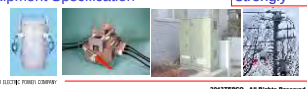


3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configurations

➢Improvement of Distribution Equipment Specification

Rerationing each other strongly



3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configuration

History of TEPCO Distribution System

- Individual Distribution System (No Interconnection) → Same as BPC's current system
- Multi-Dividing & Multi-Connecting (MD-MC) System
  - Immediate Isolation of Fault Section by Time-Limit Changeover Device
  - Minimizing Power Interruption Area in the event of Fault
- Distribution Automation System [DAS]
  - Remote Operation of Switches based on MD-MC System
  - Effective Use of Facilities (Maximizing Loading Level)
  - Minimizing Power Interruption Area in the event of Fault
- Further Reliability Improvement
  - Main & Reserve System
  - Loop System (Closed)
  - Spot Network (SPN) System (22kV only)

3. Improvement of System Reliability (Shortening of the power outage)

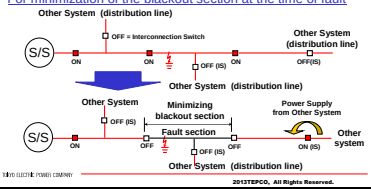
➢Distribution System configuration

Multi-Dividing & Multi-Connecting System

○ Dividing a distribution line into several sections

○ Installing interconnection switches to each sections with other system

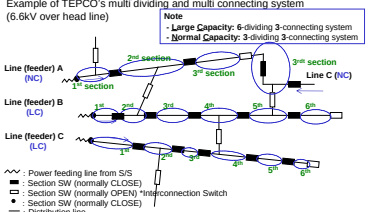
For minimization of the blackout section at the time of fault



3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configuration

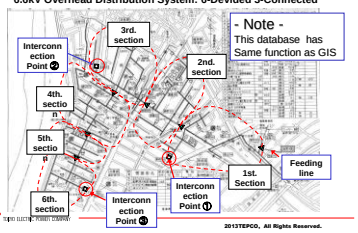
Example of TEPCO's multi dividing and multi connecting system (6.6kV over head line)



3. Improvement of System Reliability (Shortening of the power outage) Reference

➢Distribution System configuration

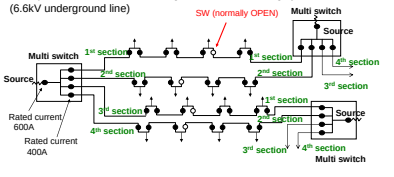
6.6kV Overhead Distribution System: 6-Devided 3-Connected



3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configuration

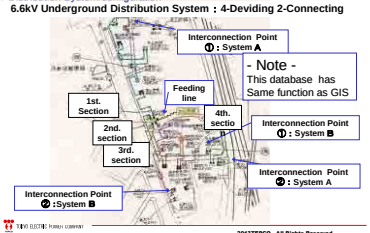
Example of TEPCO's multi dividing and multi connecting system (6.6kV underground line)



3. Improvement of System Reliability (Shortening of the power outage) Reference

➢Distribution System configuration

6.6kV Underground Distribution System ; 4-Deviding 2-Connecting



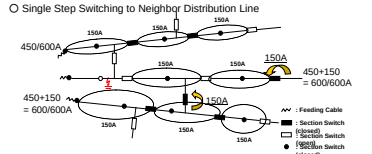
3. Improvement of System Reliability (Shortening of the power outage)

Reference

➢Distribution System constitution

Loading Level and System Operation in 6-Devided 3-Connected System

- Continuous Current Rating; 450A, Loading Level ; 75% (450/600)
- Over Load Current Rating; 600A
- Single Step Switching to Neighbor Distribution Line



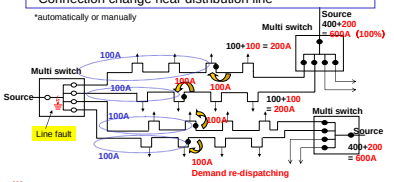
3. Improvement of System Reliability (Shortening of the power outage)

Reference

Example of the operation rate and system operation of 4 divide and 2 connected system

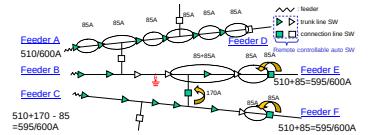
- Continuous capacity : 400A (operation rate: 67%)
- Connection change near distribution line

*automatically or manually



3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configuration (DAS: Distribution Automation System)



- Automatic Switching (fault condition)
- Manual Switching (planned)

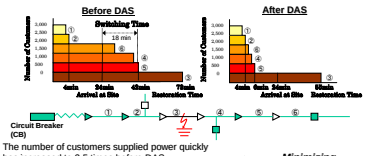
The System calculate re-dispatching method and done switching automatically in case of fault occurs

3. Improvement of System Reliability (Shortening of the power outage)

Reference

➢Distribution System configuration (DAS: Distribution Automation System)

Minimizing Power Interruption Area & Restoration Time (example)



The number of customers supplied power quickly has increased to 2.5 times before DAS.

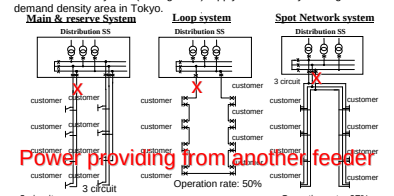
Interruption duration after DAS has been reduced to approximately 10% (average) before DAS.

Minimizing Restoration Time

3. Improvement of System Reliability (Shortening of the power outage)

➢Distribution System configuration

22kV distribution system (underground): apply it restrictively in a high demand density area in Tokyo.



Power providing from another feeder

4. Improvement of System Reliability (Fault Prevention Measures)

➢Distribution System configuration
& Improvement of Distribution Equipment Specification

Lightning Protection

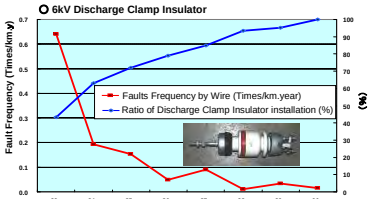
Countermeasures are Based on statistics and analyzing of fault causes

Difference insulating strength

4. Improvement of System Reliability (Fault Prevention Measures)

➢Lightning Protection

O 6kV Discharge Clamp Insulator



4. Improvement of System Reliability (Fault Prevention Measures)

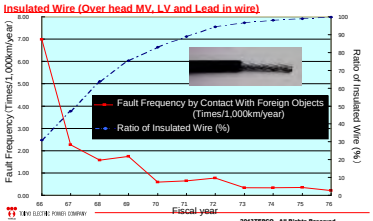
➢Lightning Protection

- **Transformers with built-in arrester are used in TEPCO in case of new installation.**

4. Improvement of System Reliability (Fault Prevention Measures)

➢Contact protection

Insulated Wire (Over head MV, LV and Lead in wire)

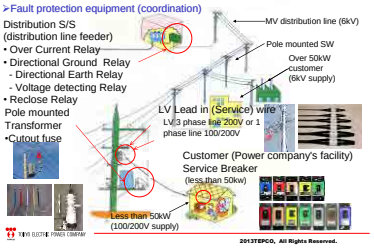


4. Improvement of System Reliability (Fault Prevention Measures)

➢Fault protection equipment (coordination)

Distribution S/S (distribution line feeder)
- Over Current Relay
- Directional Ground Relay
  - Directional Earth Relay
  - Voltage detecting Relay
- Recluse Relay

Pole mounted Transformer
- Cutout fuse



5. Maintain appropriate Voltage

➢Japanese electric power supply regulation

Voltage Maintaining by distribution division

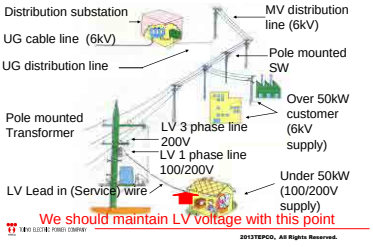
The LV supply Voltage regulation

Standard voltage	Sustaining voltage
100 V	101 V±6 V
200 V	202 V±20 V

※ The MV supply voltage does not have the national regulation.

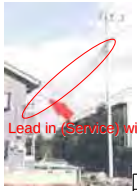
Keep sustain appropriate Voltage
- Supply Voltage control on the S/S (LDC: Line voltage drop compensator)
- Management of pole Transformer tap
- countermeasures distribution line facility (MV & LV line, service wire etc.)

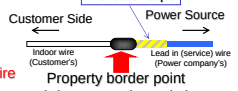
5. Maintain appropriate Voltage



We should maintain LV voltage with this point

5. Maintain appropriate Voltage



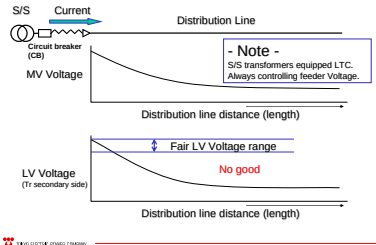


Property border point (wire connecting point)

We should keep sustaining voltage this point

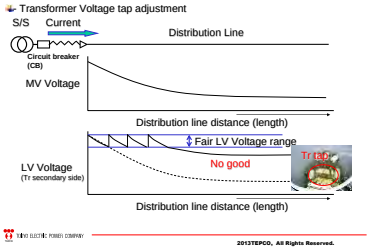
Standard voltage	Sustaining voltage
100 V	**101 V±6 V**
200 V	**202 V±20 V**

5. Maintain appropriate Voltage



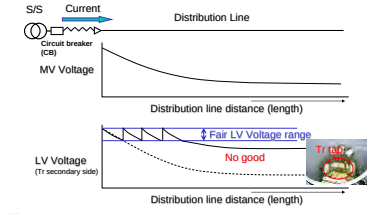
5. Maintain appropriate Voltage

Transformer Voltage tap adjustment



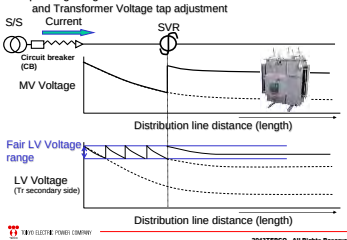
5. Maintain appropriate Voltage

- Transformer Voltage tap adjustment



5. Maintain appropriate Voltage

- Step Voltage Regulator on the MV line and Transformer Voltage tap adjustment



5. Maintain appropriate Voltage

- another countermeasures
  - Increase MV line cross section conductors
  - Increase MV line length
  - Divide demand
  - Establish new distribution line
  - Establish new substation Etc.

6. Summary

Planning will be determined by the data of the current situation and Historical facts. Therefore, by recording various data(the cause of the accident, facilities, equipment etc.), analyze, and manage, please control the fact of BPC's future.

Thank you for your kind attention!!

Smart Grid (Overview of Smart Grid in TEPCO)

TEPCO's Challenges towards Smarter Grid

Position of TEPCO
- Service Area : 39,000 km² — One-tenth of Japan's land area
- Population : 45 million
- Electricity Sales : 270 billion kWh (FY 2011)
- Peak Demand : 64.3 GW (July 2001) — One-third of Japan's total demand; 70% of the demand within a 40km radius of Tokyo

May 14, 2013

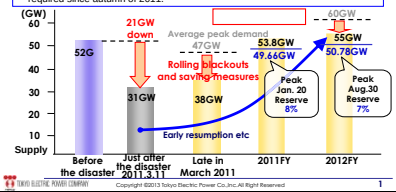
Masahiro Myoga
Manager,
Distribution Department
Power Grid Company
Tokyo Electric Power Co.,Inc.

TOKYO ELECTRIC POWER CO.,INC.

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(1) Decreased supply capacity due to the earthquake

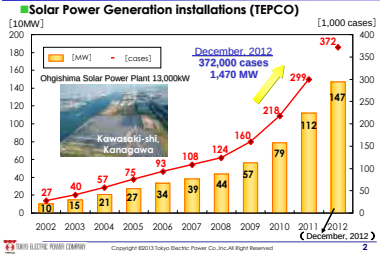
- About 21GW of Nuclear, Thermal and Hydro power plants were damaged.
- In spite of early resumption and emergency installation of facilities, demand was forcefully restricted via rolling blackouts and legal measures.
- Given the insufficient supply capacity, electricity saving measures has been required since autumn of 2011.



1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

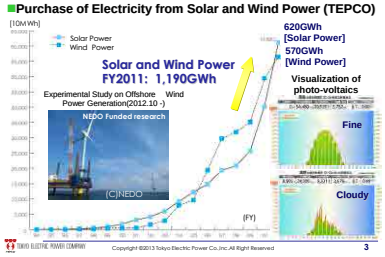
(2) Integration of Renewable Energy

Solar Power Generation installations (TEPCO)



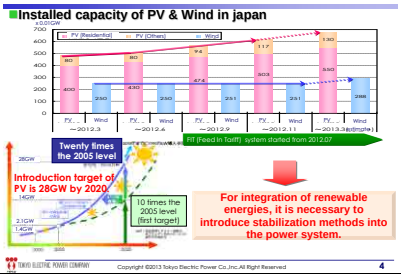
1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

Purchase of Electricity from Solar and Wind Power (TEPCO)



1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

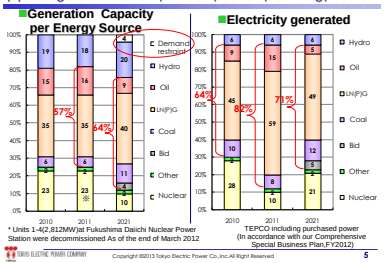
Installed capacity of PV & Wind in japan



For integration of renewable energies, it is necessary to introduce stabilization methods into the power system.

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(3)Changes in Power Output Composition per Energy Source

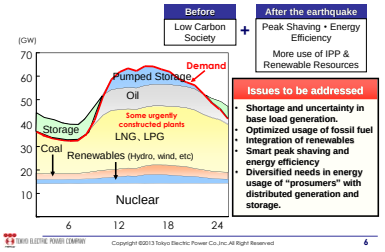


* Units 1-4(2,812MW)at Fukushima Daiichi Nuclear Power Station were decommissioned As of the end of March 2012

TEPCO including purchased power (In accordance with our Comprehensive Special Business Plan,FY2012)

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(4) Supply demand balance after the Great Earthquake



Issues to be addressed
- Shortage and uncertainty in base load generation.
- Optimized usage of fossil fuel
- Integration of renewables
- Smart peak shaving and energy efficiency
- Diversified needs in energy usage of "prosumers" with distributed generation and storage.

2. Towards optimization of energy usage with our customers and society

◆Smart grid in Tepco

A Platform to innovate energy service with customers and society and to improve energy efficiency and optimize usage via the coordination of demand and supply

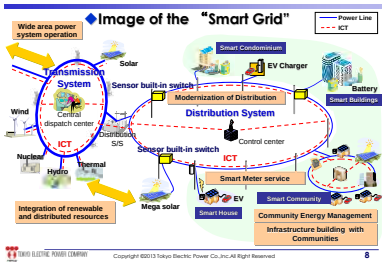
◆Objective

To establish an advanced "smart grid", in which both grid generators and customers are mutually coordinated, in order to realize the following objectives as "a network service integrator"

- ☐ Provision of more options for customers to meet diverse needs
  - ✓ Various tariff and energy management services via business alliances
- ☐ Additional reduction of peak demand and more efficient use of facilities
  - ✓ Developments and proposals for new services with smart meters, energy solutions and so on.
- ☐ Grid Integration of a large amount of renewable resources and coordination with on-site generation systems
  - ✓ Enhancement of neutrality and fairness in network service divisions establishment of a network, in which efficiency and the reliability of facilities are improved by ICT

2. Towards optimization of energy usage with our customers and society

◆Image of the "Smart Grid"



3. Efforts in realize "Smart Grid"

(1) Key concepts

1. Efficient & optimized energy usage with customers and society.

① Active adoption of Smart Meters. / Expansion of new services.
② Construction of Demand-Response program for efficient energy usage with demand side & supply side.
③ Realization of Smart Communities/Towns with customers & areas.

2. Integration of renewable and distributed resources with the help of the modernization of power networks.

① Upgrading distribution network by taking advantage of ICT.
② Widening of power system operation.
③ Development of next-generation transmission & distribution network system concerned with integration of residential PV.
④ Development of integrated control of battery energy storage.

(2) Positive introduction and practical use of a smart meter system

I. Active adoption of Smart Meters / Expansion of new services

- The advantage of smart meter implementation (27 million sets)

Operation cost reduction
Wider Tariff choices
The visualization of power consumption data
Demand control by two-way communication
Creation of new value-added service

→ ■Operational reforms ■Better customer service ■Cut back on investments by DSM

- The deployment prospect of smart meters

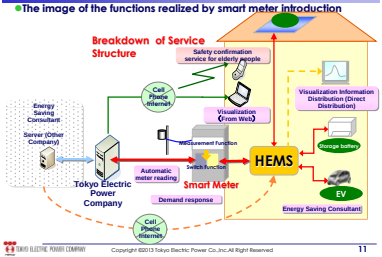
RFP : Request For Proposal

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Meter installation	Mechanical meter			Smart Meter installation							
	About 2 million sets		About 5 million sets	About 14 million sets				About 27 million sets			

If exchanges according to a legal term etc.

Deployment of new service

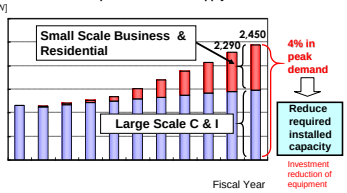
- The image of the functions realized by smart meter introduction



II. Construction of Demand-Response program for efficient energy usage with demand side & supply side

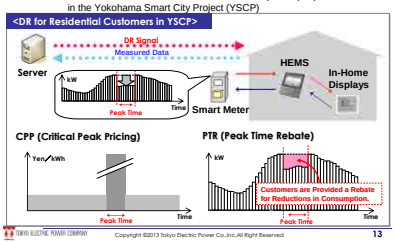
- Planned Demand Response in Demand-Supply Plan

[MW]

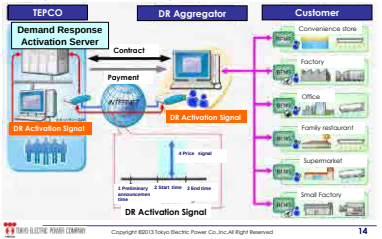


- Research on Introducing Dynamic Pricing for Residential Customers
  - Measurement and Verification of Demand Response (DR) in the Yokohama Smart City Project (YSCP)

<DR for Residential Customers in YSCP>



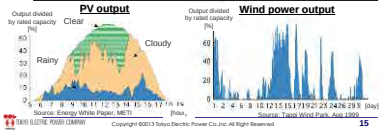
- Request of Demand Response



(3) Integration of renewable and distributed resources by modernizing power networks

- Grid Intermittent output of PV and wind Power
  - Intermittent output of PV and wind power is subject to weather condition

☐ Network Reinforcement is required for more RE integration to realize interactive coordination between grids and generators
→Smart Grid with interactive communication
☐ Much discussion is needed to decide who should pay the reinforcement costs



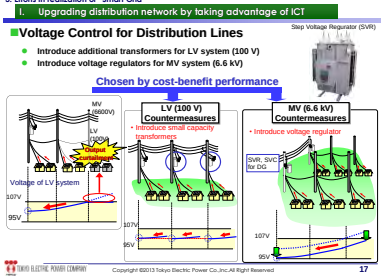
- Integration of Renewable Energy

	Challenges	Solutions
Voltage (Developed)	**Overvoltage on distribution system** ● Voltage rises at the end of the distribution lines due to renewable energies	・Additional transformers ・Installation of voltage regulators
Frequency (Developing)	**Absorption of surplus power** ● PV output causes surplus power during off peak demand period	・Curtailment of PV ・Electrification ・Widening of power system operation
	Improvement in output estimation ● How to estimate intermittent output	・Estimation of intermittent output
	Sufficient frequency control capability ● Insufficient frequency control of generation system due to renewable energies	・Integrated system of batteries for generation control ・Widening of power system operation

I. Upgrading distribution network by taking advantage of ICT

- Voltage Control for Distribution Lines
  - Introduce additional transformers for LV system (100 V)
  - Introduce voltage regulators for MV system (6.6 kV)

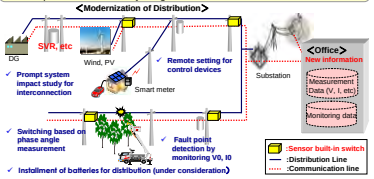
Chosen by cost-benefit performance



- Optimization of Distribution Network

Merits of monitoring and control system with sensor built-in switch

- Securing power quality using measurement data (V, I) for RE integration study
- Quick fault detection and prompt restoration to prevent faults
- Improvement of efficiency using the remote control

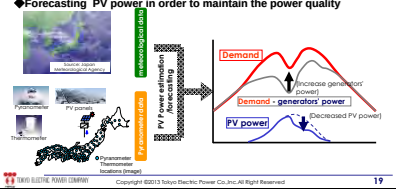


II. Development of next-generation transmission & distribution network system concerned with integration of residential PV

- Demonstration project of forecast technologies for photovoltaic power generation

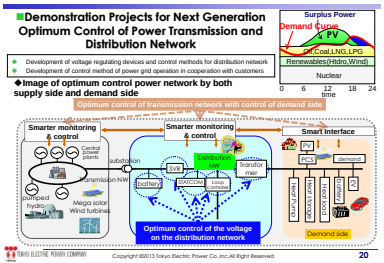
◆ Development of a method to estimate the current photovoltaic power generation output from weather data or sunlight data
◆ Develop method to forecast the photovoltaic power generation output

◆Forecasting PV power in order to maintain the power quality



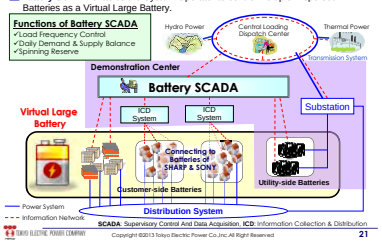
- Demonstration Projects for Next Generation Optimum Control of Power Transmission and Distribution Network

◆Image of optimum control power network by both supply side and demand side

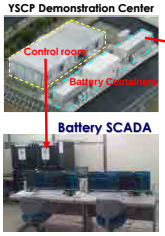


III. Development of integrated control of battery energy storage

■Battery SCADA enables the System Operator to control Multiple Dispersed Batteries as a Virtual Large Battery.



YSCP Demonstration Center



Lithium ion Batteries of HITACHI, MEIDENSHA/NEC, TOSHIBA from the right

HITACHI	250kW/51kWh or 100kW/100kWh※1
MEIDENSHA /NEC	250kW/ 250kWh※1
TOSHIBA	300kW/ 100kWh※2

※1 : nominal capacity ※2: operational capacity

4. Conclusions

Change in Demand-Supply Structure

1. Efficient & optimized energy usage with customers and society
2. Integration of renewable and distributed resources with the help of the modernization of power networks

S+3E Achievements
- Energy security
- Environmental conservation
- Economy

Safety

① Supply Side: Integration of RES DER, New Supply Capacity
X
② Demand Side: Various energy services, Efficient energy usage

Flexible & Robust

"Smart Grid"

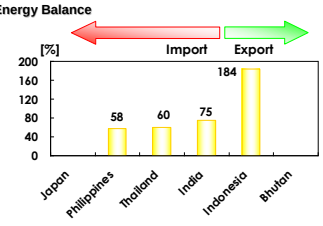
- Innovate our energy services with our customers and society
- Realize a platform that enables efficient and optimized energy usage with a demand and supply side perspective

What do you think?

What is your smart grid?

What is your smart grid?

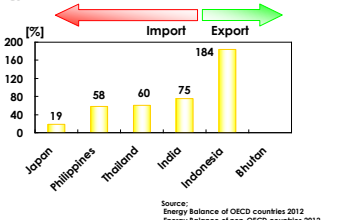
■Energy Balance



Source:
Energy Balance of OECD countries 2012
Energy Balance of non-OECD countries 2012

What is your smart grid?

■Energy Balance



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Energy Balance of OECD countries 2012
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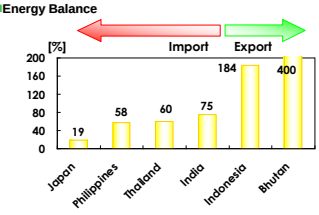
What is your smart grid?

■Energy Balance



Source;
Energy Balance of OECD countries 2012
Energy Balance of non-OECD countries 2012

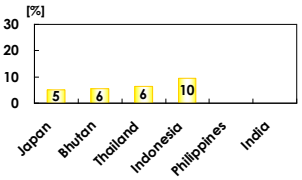
What is your smart grid?

★SUBARU Plug-In Stella ★NISSAN LEAF ★HONDA FIt EV

★CHAdeMO DC Fast Charger ★MITSUBISHI i-MiEV ★TOYOTA eQ

What is your smart grid?

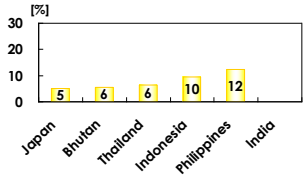
■Transmission & Distribution Loss



Source: JEPIC Report

What is your smart grid?

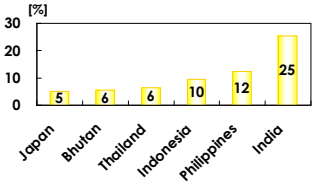
■Transmission & Distribution Loss



Source: JEPIC Report

What is your smart grid?

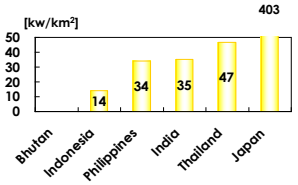
■Transmission & Distribution Loss



Source: JEPIC Report

What is your smart grid?

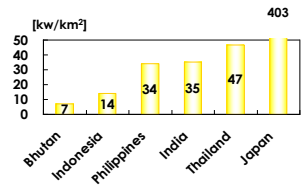
■Load Density



Source: JEPIC Report

What is your smart grid?

■Load Density



Source: JEPIC Report

Presentation Materials of fifth Workshop

Priority Issue Solving

Issue Solving Activity

July 2013
Tokyo Electric Power Company

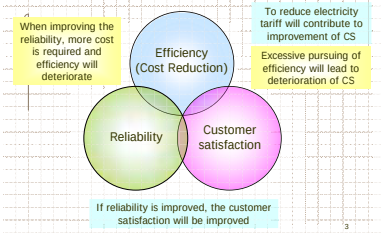
1

Relationship between Supplier and Customer

- In case of general products
  - Customer selects the product (supplier)
- In case of power sector
  - General customers have no choice to select their supplier
  - Most citizens have no choice but to purchase the product (electricity) with determined cost and quality
- Less incentive for power suppliers to improve the power quality or customer satisfaction

2

- Major Three Factors that Power Sector shall aim
- Be gradually improved in well balance



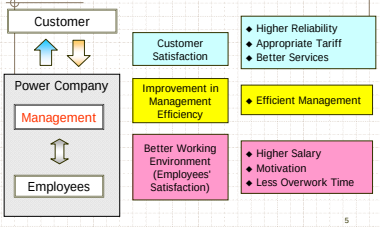
3

Opportunities to utilize TQM Activity

- Improvement of system reliability or customer satisfaction with less investment
  - There are some measures by ingenuity without so much investment.
- Efficient Investment
  - Plan with higher effect shall be prioritized
- Improvement of work efficiency
  - Spare power can be utilized to improvement of system reliability or customer satisfaction

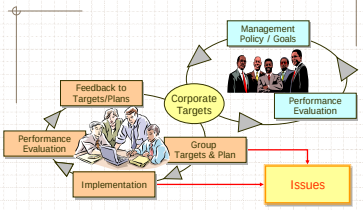
4

Situations Surrounding Power Company



5

Manager's Role & Responsibility



6

What is Priority Issue (PI) Solving Activity?

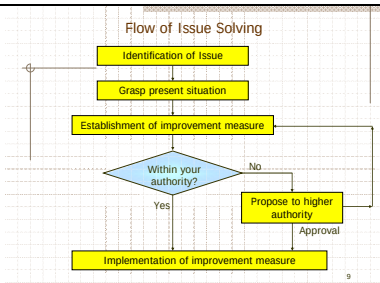
7

Objectives

- The active and proper contributions of the middle-class managers are indispensable to improving the management situations at your office.
- The main objective is to enable the middle-class managers to tackle…
  - Issues/problems to achieve their group targets / the management goals
  - Issues/problems that are significant in their working places

8

Flow of Issue Solving



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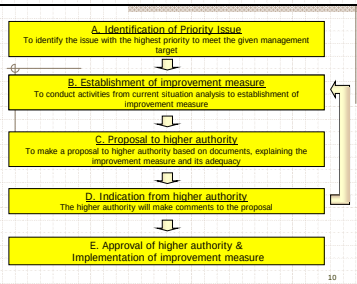


10

A. Identification of Priority Issue

- Identify a problem/issue
  - Look at things from customers' viewpoints. (if you are a customer)
  - Think about what the ideal situations are.
- Issues to be solved with top priority to realize visions of the company
  - Improvement of supply reliability, Loss reduction, Improvement of customer satisfaction, Securing of personnel safety etc. (for example)
  - Identify issue (theme) specifically

11

B. Establishment of Improvement Measure

1. Evaluation, Quantification of Current Badness
2. Cause Analysis
3. Plan out various Measures
4. Evaluation of Cost-Benefit Performance
5. Determination of Implementing Measure

12

B-1. Evaluation, Quantification of Current Badness

- Use data, facts, and common words in order to describe actual phenomenon precisely in
  - understanding current situations,
  - analyzing problems, and
  - confirming impacts of measures / verifying your assumption.
- Understand things based on data, instead of judging things only on speculation or in the illusionary belief.

13

How to handle the data

- The aim of using data is to solve problems, not to gather more data.
  - Step 1: Think about what you want to describe, analyze, confirm, verify.
  - Step 2: Think about how you should handle or show the data. It is because its aim is to make people understand easily and correctly or to appeal to people.

14

How to handle the data

- The use of data is to help right understandings and prevent interpersonal misunderstandings
- Data contradicting with your story should not be neglected
- Unreliable data should not be used
- Data must be gathered in consistent and sequential ways

15

B-2. Cause Analysis

- Multi-aspect cause analysis
  - To identify all considerable causes
  - Fishbone diagram
- Evaluation of significance of causes by using actual data
  - Frequency of occurrence
  - Magnitude of impact
- Refine root causes in order to require measures easily

16

B-3. Plan out Various Measures

- Measures corresponding with Causes from many aspects
  - Identify various potential solutions and measures. The solutions and measures are not only ONE.
  - Get rid of your prejudice or bias against the present situations.

17

B-4. Evaluation of Cost-Benefit Performance

- Evaluation of benefit
  - Expected timing of the benefit to arise
- Evaluation of cost
  - Expected timing of required payment
  - Possibility of budget procurement
- Consider time value
  - 1 Nu. (at present) ≠ 1 Nu. (1 year after)

18

B-5. Determination of Implementing Measure

- Comparison analysis & prioritization of several measures
  - Advantage/Disadvantage of application of measures
  - Cost-benefit performance
  - Difficulty
  - Amount of resource injection
  - Timing when implementation is possible

19

Formulate Implementation Plan

- Resource to be injected
  - Fund, manpower
- Timing and schedule of implementation
- Expected effect
- Other items to be considered
  - Confirm that any other problem will not occur by taking a solution/measure to be selected.
  - Have a viewpoint that a selected solution and measure will have large impacts if it is shared with other people. (lateral spreading)

20

C. Proposal to Higher Authority

- Preparation of presentation material
  - Easily understandable explanation
    - Easily understandable logic
    - Straightforward storyline
    - Short-time, limited main points
  - Easy-to-read documents
    - Effective use of figures & tables
    - What is the key message from figures/tables

21

When you carry out **PI Solving Activity**, Repeat **Self-Questionings** to achieve good performance

1. Are there still any other Causes that result in Badness?
2. Are there still any Alternative Solutions, that you have not yet found out?
3. Did you compare Solutions well enough in light of Cost and Effectiveness?
4. Did you prepare multiple Solutions and analyze them well enough, so that your Boss can compare and judge with your proposals?

22

Issue Solving Activity

- Work should not always be done only by yourself
  - Instructing Junior Staffs for Information gathering
  - Brain storming with other managers/officers
  - Discussion with higher authority
- Not special work (Routine work)
  - Always consider to improve current situation
- Make story and logic to convince higher authority using data & facts

23

Issue Solving Activity

- Not only beneficial for the company, but also for you
  - Save time
    - Family benefit; Enjoy private time
  - Save money
    - Money benefit; Increasing your wage
- Don't give up solving problems or issues.
  - There are many measures

24

Thank you for your kind attention

25

Issue Solving Activity

July 2013
Tokyo Electric Power Company

1

Future Schedule

- Next mission: the end of August
  - Discussion with each team (Seki, Fujitani)
- Last presentation session
  - 25th or 26th September
- Training in Japan: 2 weeks x 12 persons
  - The middle of November

2

Selection Criteria of Training in Japan

- Evaluation from Japanese Adviser (individual): max 10 points
- Evaluation of Output (team) : max 15 points
  - Final proposal
  - Third country survey report
- Others (individual): max 5 points
  - Participation to the discussion
  - Daily efforts

3

Judging Points of Proposal

- Analysis by using data & facts
  - Current badness, cause analysis
- Comparison with other measures
  - Selection of most appropriate measure
- Story of the Proposal
  - Easily understandable logic
- Implementation plan
  - What you want, how to do, when, who

4

Third Country Report

- By 9th August submit to Ms. Orui
  - By the end of July: Draft version
- What did you learn?
- How to use the things that you learnt for your PI solving activity?
- How to use the things that you learnt for your work in promoting BPC's business efficiency?

5

When you carry out **PI Solving Activity**, Repeat **Self-Questionings** to achieve good performance

1. Are there still any other Causes that result in Badness?
2. Are there still any Alternative Solutions, that you have not yet found out?
3. Did you compare Solutions well enough from Cost and Effectiveness?
4. Did you prepare multiple Solutions and analyze them well enough, so that your Boss can compare and judge with your proposals?

6

Thank you for your kind attention

Don't give up solving issues.
There are many measures

7

Smart Grid System

TEPCO's Challenges towards Smarter Grid

TEPCO will Establish the "SMART GRID" in Cooperation with Customers & Society

Following the Great East Japan Earthquake, amidst tremendous changes occurring in the energy supply and demand structure, TEPCO will implement energy reforms to realize efficient and optimal energy usage for our customers and greater society.

Position of TEPCO
- Service Area : 39,000 km² — One-tenth of Japan's land area
- Population : 45 million
- Electricity Sales : 270 billion kWh (FY 2011)
- Peak Demand : 64.3 GW (July 2001) — One-third of Japan's total demand; 70% of the demand within a 40km radius of Tokyo

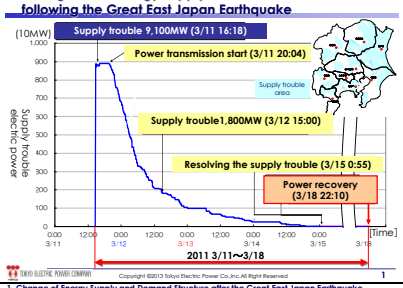
July 18, 2013

Masaki Iwama

TEPCO
Tokyo Electric Power Co.,Inc.

TOKYO ELECTRIC POWER CO.,INC.

1. Change in the Energy Supply and Demand Structure following the Great East Japan Earthquake

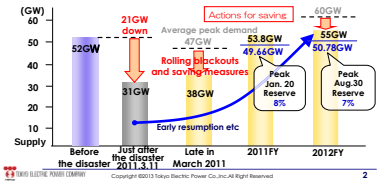


1

1. Large scale Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(1) Decreased supply capacity due to the earthquake

- About 21GW of Nuclear, Thermal and Hydro power plants were damaged.
- In spite of early resumption and emergency installation of facilities, demand was forcefully restricted via rolling blackouts and legal measures.
- Given the insufficient supply capacity, electricity saving measures has been required since autumn of 2011.



2

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

[Examples of Restored Disaster Equipment]

■Hirono Thermal Power Station

Shortly after disaster

3 months later

■Hitachinaka Thermal Power Station

Shortly after disaster

3 months later

3

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

[Measures to Secure Electric Power Supply Capacity]

■Re-start of aged power stations after a long term suspension

Re-started Yokosuka Thermal Power Station Unit 3&4 boiler

Operating Unit 3 turbine generator

■Urgent installation of new power supply facilities (284MW)

Chiba Power Station (PS) (3 gas turbines)

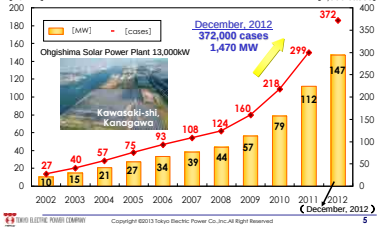
Sodegaura PS (102 sets of gas engines)

4

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(2) Integration of Renewable Energy

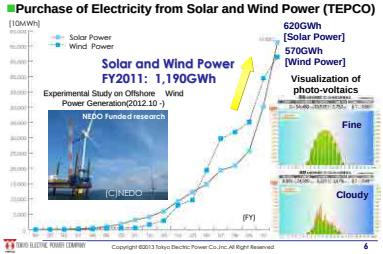
■Solar Power Generation installations (TEPCO)



5

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

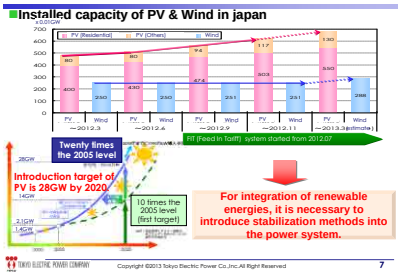
■Purchase of Electricity from Solar and Wind Power (TEPCO)



6

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

■Installed capacity of PV & Wind in japan



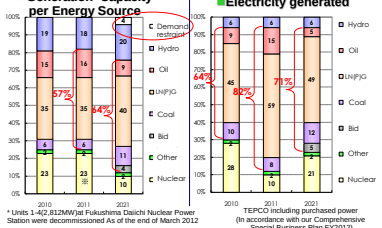
7

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(3) Changes in Power Output Composition per Energy Source

■Generation Capacity per Energy Source

■Electricity generated



* Units 1-4(2,812MW)at Fukushima Daiichi Nuclear Power Station were decommissioned As of the end of March 2012

TEPCO including purchased power (In accordance with our Comprehensive Special Business Plan,FY2012)

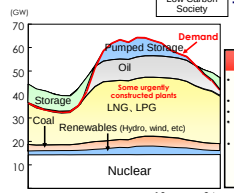
8

1. Change of Energy Supply and Demand Structure after the Great East Japan Earthquake

(4) Supply demand balance after the Great Earthquake

Before: Low Carbon Society

After the earthquake: Peak Shaving・Energy Efficiency; More use of IPP & Renewable Resources



Issues to be addressed

- Shortage and uncertainty in base load generation.
- Optimized usage of fossil fuel
- Integration of renewables
- Smart peak shaving and energy efficiency
- Diversified needs in energy usage of "prosumers" with distributed generation and storage.

2. Towards optimization of Energy Usage with our Customers and Society

"S"+Triple"E"s:
- Energy security
- Environmental conservation
- Economy
- Safety

①Supply Side
- Integration of RES DER
- New Supply Capacity

X

②Demand Side
- Various energy services
- Efficient energy usage

❸ Cope with changes in supply and demand side utilizing ICT flexibly

Towards optimization of energy usage with our customers and society.

2. Towards optimization of energy usage with our customers and society

◆Smart grid in Tepco

A Platform to innovate energy service with customers and society and to improve energy efficiency and optimize usage via the coordination of demand and supply

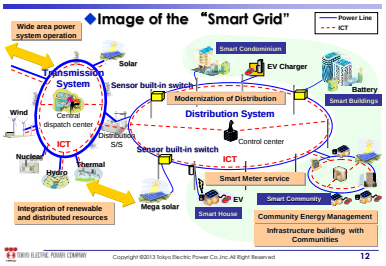
◆Objective

To establish an advanced "smart grid", in which both grid generators and customers are mutually coordinated, in order to realize the following objectives as "a network service integrator"

- Provision of more options for customers to meet diverse needs
  - ✓ Various tariff and energy management services via business alliances
- Additional reduction of peak demand and more efficient use of facilities
  - ✓ Developments and proposals for new services with smart meters, energy solutions and so on.
- Grid Integration of a large amount of renewable resources and coordination with on-site generation systems
  - ✓ Enhancement of neutrality and fairness in network service divisions establishment of a network, in which efficiency and the reliability of facilities are improved by ICT

2. Towards optimization of energy usage with our customers and society

◆Image of the "Smart Grid"



3.Efforts in realize "Smart Grid"

(1) Key concepts

1. Efficient & optimized energy usage with customers and society.

❶ Active adoption of Smart Meters. / Expansion of new services.
❷ Construction of Demand-Response program for efficient energy usage with demand side & supply side.
❸ Realization of Smart Communities/Towns with customers & areas.

2. Integration of renewable and distributed resources with the help of the modernization of power networks.

❶ Upgrading distribution network by taking advantage of ICT.
❷ Widening of power system operation.
❸ Development of next-generation transmission & distribution network system concerned with integration of residential PV.
❹ Development of integrated control of battery energy storage.

3. Efforts in to realize "Smart Grid"

(2) Positive introduction and practical use of a smart meter system

I. Active adoption of Smart Meters / Expansion of new services

●The advantage of smart meter implementation (27 million sets)

- Operation cost reduction
- Wider Tariff choices
- The visualization of power consumption data
- Demand control by two- way communication
- Creation of new value-added service

→ ■Operational reforms ■Better customer service ■Cut back on investments by DSM

●The deployment prospect of smart meters

RFP : Request For Proposal

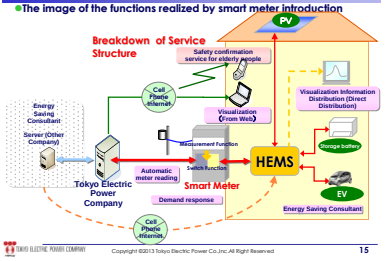
	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Meter installation	Mechanical meter										
	About 2 million sets	About 5 million sets		About 14 million sets						About 27 million sets	

Smart Meter installation

Deployment of new service

3. Efforts in to realize a "Smart Grid"

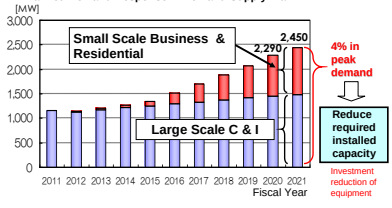
●The image of the functions realized by smart meter introduction



3. Efforts in to realize "Smart Grid"

II. Construction of Demand-Response program for efficient energy usage with demand side & supply side

●Planned Demand Response in Demand-Supply Plan



4% in peak demand

Reduce required installed capacity

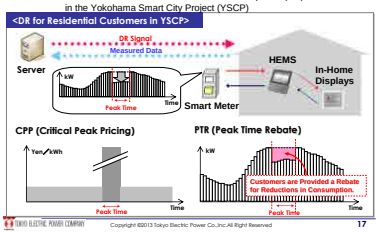
Investment reduction of equipment

3. Efforts in to realize "Smart Grid"

●Research on Introducing Dynamic Pricing for Residential Customers

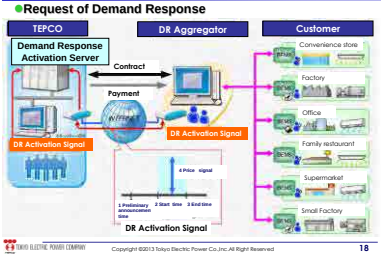
• Measurement and Verification of Demand Response (DR) in the Yokohama Smart City Project (YSCP)

<DR for Residential Customers in YSCP>



3. Efforts in to realize "Smart Grid"

●Request of Demand Response



3. Efforts in to realize "Smart Grid"

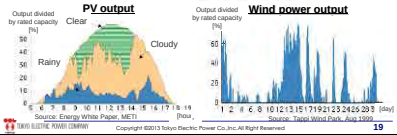
(3) Integration of renewable and distributed resources by modernizing power networks

■Grid Intermittent output of PV and wind Power

- Intermittent output of PV and wind power is subject to weather condition

☐ Network Reinforcement is required for more RE integration to realize interactive coordination between grids and generators
→Smart Grid with interactive communication

☐ Much discussion is needed to decide who should pay the reinforcement costs



3. Efforts in to realize "Smart Grid"

■Integration of Renewable Energy

	Challenges	Solutions
Voltage (Developed)	**Overvoltage on distribution system** ● Voltage rises at the end of the distribution lines due to renewable energies	・Additional transformers ・Installation of voltage regulators
Frequency (Developing)	**Absorption of surplus power** ● PV output causes surplus power during off peak demand period	・Curtailment of PV ・Electrification ・Widening of power system operation
	Improvement in output estimation ● How to estimate intermittent output	・Estimation of intermittent output
	Sufficient frequency control capability ● Insufficient frequency control of generation system due to renewable energies	・Integrated system of batteries for generation control ・Widening of power system operation

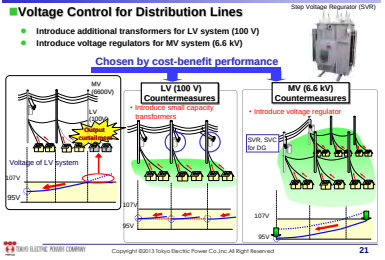
3. Efforts in realization of "Smart Grid"

I. Upgrading distribution network by taking advantage of ICT

■Voltage Control for Distribution Lines

- Introduce additional transformers for LV system (100 V)
- Introduce voltage regulators for MV system (6.6 kV)

Chosen by cost-benefit performance

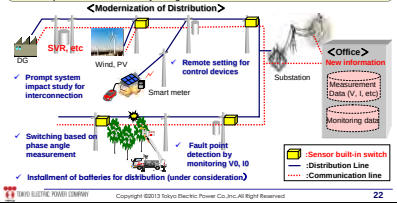


3. Efforts in realization of "Smart Grid"

■Optimization of Distribution Network

Merits of monitoring and control system with sensor built-in switch

- Securing power quality using measurement data (V, I) for RE integration study
- Quick fault detection and prompt restoration to prevent faults
- Improvement of efficiency using the remote control



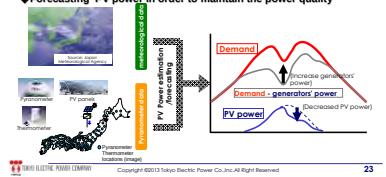
3. Efforts in realization of "Smart Grid"

II. Development of next-generation transmission & distribution network system concerned with integration of residential PV

■Demonstration project of forecast technologies for photovoltaic generation

- Development of a method to estimate the current photovoltaic power generation output from weather data or sunlight data
- Develop method to forecast the photovoltaic power generation output

◆Forecasting PV power in order to maintain the power quality

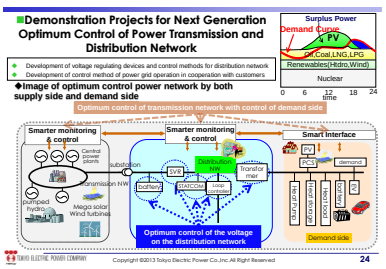


3. Efforts in realization of "Smart Grid"

■Demonstration Projects for Next Generation Optimum Control of Power Transmission and Distribution Network

- Development of voltage regulating devices and control methods for distribution network
- Development of control method of power grid operation in cooperation with customers

◆Image of optimum control power network by both supply side and demand side



4. Conclusions

Change in Demand-Supply Structure

1. Efficient & optimized energy usage with customers and society
2. Integration of renewable and distributed resources with the help of the modernization of power networks

S+3E Achievements

①Supply Side
- Integration of RES DER,
- New Supply Capacity

X

②Demand Side
- Various energy services,
- Efficient energy usage

Flexible & Robust "Smart Grid"

- Innovate our energy services with our customers and society
- Realize a platform that enables efficient and optimized energy usage with a demand and supply side perspective

● Amidst current restoration efforts, TEPCO will work towards the establishment of the SMART GRID in cooperation with our customers and society to achieve efficient and optimized energy usage leading to maximization of social benefits.

事故点探査の結果報告

ブータン電力公社（BPC）における事故点探査結果について

東京電力株式会社
2013年7月

TOKYO ELECTRIC POWER COMPANY

1．背景

- ✓ ブータン地方電化推進プロジェクトフェーズ2実施中
  2013年の電化率100%を目指し，地方電化展開中
  プロジェクト期間：2012年3月～2014年7月
- ✓ 優先課題解決活動（PI活動）の実施でブータン電力公社（BPC）職員の課題解決能力向上を支援
- ✓ 5～6テーマを選定し，課題解決にむけ活動を展開
- ✓ 1テーマとして事故点探査手法の改善をピックアップ

2．課題（事故点探査の改善）について

■ BPCの現状

- 適切な事故点探査機材がない
  （機材はあるがうまく扱えない） ⇨ ✓ **探せない** ✓ **事故設備放置**
- 設備マップが存在しない
- 事故点探査に時間がかかる
- 多くの人員を配置 ⇨ ✓ **非効率** ✓ **サービス低下**

課題の解決により，

- ✓ 効率化（地方電化へ人員配分，設備の改修利用）
- ✓ 信頼度向上（設備信頼度，供給信頼度向上）
- ✓ 顧客満足度向上（早期送電）

事故点探査手法の改善を目指して取り組む

3．派遣概要

■ 目的
- 一手法の紹介としてLUPINにて現地探査を実施
  （BPC技術者の理解向上，解決支援）
- 日本製機材（LUPIN）の紹介

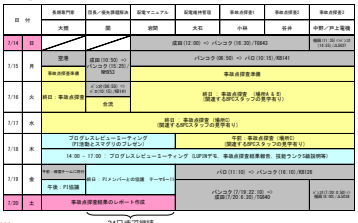
■ 要員
- 東電配電保守員 2名 ＋ 戸上電機 1名
  東京電力　東京支店　小林
  東京電力　埼玉支店　谷井
  戸上電機　中野氏
- プロジェクトメンバー
  関，岩間，大石

■ 内容
- ✓ 事前準備（現場確認と機材準備）（1日）
- ✓ 事故地中配電線の事故点探査（2.5日）
- ✓ 事故点探査に関するBPCとの協議（0.5日）

} 現地調査 計4日

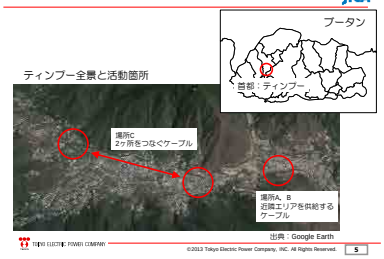
3．派遣概要

■ スケジュール



24日まで継続

4．ブータン位置情報



ティンプー全景と活動箇所

出典：Google Earth

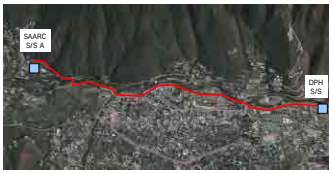
5．事故点探査現場情報

■ 場所AおよびB

出典：Google Earth

5．事故点探査現場情報

■ 場所C



出典：Google Earth

6．事故点探査の流れ

1. 事故ケーブルの特定
2. 事故ケーブルの絶縁測定
3. ケーブル導体抵抗測定: ケーブル長算出
4. 高圧プリッジ測定：事故点距離の算出
5. LUPINによる探査：詳細な事故点探査
6. 終了

6．事故点探査結果

◆ ケーブル事前情報（場所AおよびB）

ケーブル	サイズ	長さ	埋設深さ	分岐有無	使用電圧
3core XLPE	300mm²	A:600m B:500m	Over 1m	No	11kV

◆ 絶縁測定による事故状況

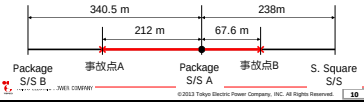
場所A	相	絶縁抵抗
対地	赤相	7.6M Ω
	黄相	< 5000M Ω
	青相	**< 15k Ω**
線間	赤－黄	< 5000M Ω
	黄－青	< 5000M Ω
	赤－青	< 5000M Ω

場所B	相	絶縁抵抗
対地	**赤相**	**3k Ω**
	黄相	< 5000M Ω
	青相	< 5000M Ω
線間	赤－黄	< 5000M Ω
	黄－青	< 5000M Ω
	赤－青	< 5000M Ω

6．事故点探査結果

◆ 高圧プリッジによる事故点距離の測定結果

場所	事前情報 ミリオームテスタおよびLUPINによる現地測定	%値	事故点までの距離
A	600 m	62.3 %	373 m
	340.5 m		**212 m**
B	500 m	28.4 %	142 m
	238 m		**67.6 m**



6．事故点探査結果

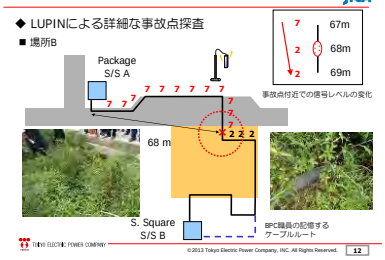
◆ LUPINによる詳細な事故点探査

■ 場所A

6．事故点探査結果

◆ LUPINによる詳細な事故点探査

■ 場所B



6．事故点探査結果

◆ ケーブル事前情報（場所C）

ケーブル	サイズ	長さ	埋設深さ	分岐有無	使用電圧
3core XLPE	300mm²	4000m	Over 1m	No	11kV

◆ 絶縁測定による事故状況

場所C	相	絶縁抵抗
対地	赤相	470M Ω
	黄相	56M Ω
	青相	200M Ω
線間	赤－黄	270M Ω
	黄－青	310M Ω
	赤－青	740M Ω

高圧プリッジ適用前の状況

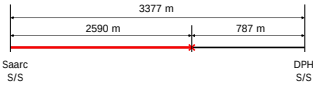
場所C	相	絶縁抵抗
対地	赤相	480M Ω
	黄相	70M Ω
	青相	**6k Ω**
線間	赤－黄	320M Ω
	黄－青	50M Ω
	赤－青	450M Ω

最終的な状況（プリッジ数度適用）

6．事故点探査結果

◆ 高圧プリッジによる事故点距離の測定結果

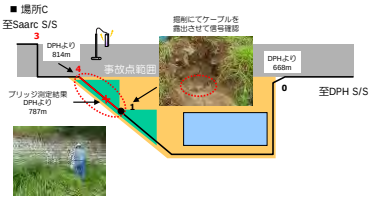
場所	事前情報 ミリオームテスタおよびLUPINによる現地測定	%値	事故点までの距離
C	4000 m	76.7 %	3068 m
	3377 m		**2590 m**



6．事故点探査結果

◆ LUPINによる詳細な事故点探査

■ 場所C



7．事故点探査結果のまとめ

◆ 場所AおよびBについて

場所	全長	高圧ブリッジ	LUPIN	差	探査時間
A	340.5 m	212 m	210 m	2 m	2時間
B	238 m	67 m	68 m	1 m	2.5時間

- 高圧ブリッジとLUPINの結果に大きな差はなくそれぞれの測定器が精度の高い結果を残した
- ただし、高圧ブリッジは全長データが重要であり正確なルート探査ができるLUPINとの併用が必要である
- LUPINより先に高圧ブリッジを実施することで絶縁抵抗の低抵抗化とLUPIN探査範囲の絞り込みができ、作業の効率化が図れる

LUPINと高圧ブリッジの併用により短時間で精度の高い結果を得られた
長距離が多い高圧ケーブルへの事故点探査手法の一例を示せた

7．事故点探査結果のまとめ

◆ 場所Cについて

- 絶縁抵抗が安定せず，LUPIN探査が困難を極めた
- 高圧ブリッジでは0.2~0.3kVまで昇圧すれば安定した電流の確保が可能
- しかし，LUPINではケーブル静電容量の影響で，160V程度でアンプが過負荷となってしまう
- よって，安定した信号電流を確保できず，難しい事故点探査となった
- 事故点抵抗がもう少し低抵抗化させられたらLUPIN探査は可能

（調査時間の関係から，低抵抗化の時間をあまり確保できなかった）

- LUPIN側の接地極を配電塔側で取ると事故点手前の水道管等に戻り信号が発生し、対地に接地極を打ち込むと事故点以降のケーブルに事故電流が確認できた。高圧ケーブル探査では遮蔽層、アーマー層の影響があるため探査状況によっては接地極を替えて確認する必要ある。

高圧ブリッジの低抵抗化によってLUPIN探査可能な状況へ進展できた
LUPIN単独で難しい事故様相への打開策の一例を示せた

8．事故点探査風景


TBM-KY

ブリッジ測定

LUPIN調整中


LUPIN探査中


信号確認のため掘削


営業所にて

Presentation Materials of sixth Workshop

Earthing/Grounding in Japan

Earthing/Grounding in Japan

May 2014
Tokyo Electric Power Company

TOKYO ELECTRIC POWER COMPANY

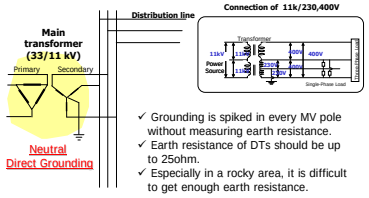
Agenda

§ .1 Current Situation of Earthing/Grounding in Bhutan
§ .2 Network Earthing/Grounding in Japan
§ .3 In-house Earthing/Grounding in Japan
§ .4 Recommendation

Chapter.1 Current Situation of Grounding in Bhutan

Network system in BPC

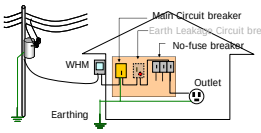
MV distribution line Grounding system in BPC



- ✓ Grounding is spiked in every MV pole without measuring earth resistance.
- ✓ Earth resistance of DTs should be up to 25ohm.
- ✓ Especially in a rocky area, it is difficult to get enough earth resistance.

Grounding system in house

Standard internal wiring in Bhutan

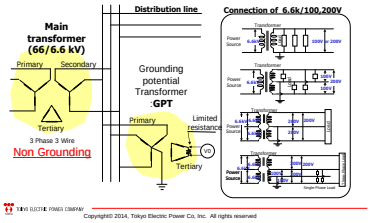


- BPC regulates a customer's grounding resistance in house at the time of application of electricity use. (good)
- ELCBs are installed in small number of households in Bhutan. (bad)

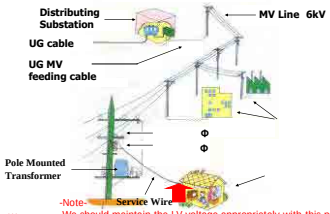
Chapter.2 Network Grounding in Japan

Network System in TEPCO

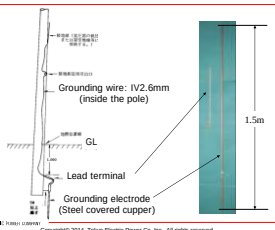
6.6kV-MV distribution line Grounding system



Overhead Distribution System



Earthing/Grounding of Poles



Chapter.2 Network Grounding in Japan

Rules, Regulation

Rules, Regulation for network grounding

➢ Regulation that Electricity Utilities must observe in Japan
"Electrical Equipment Technical Standards (EETS)"
by METI (Ministry of Economy, Trade, and Industry)
[objective] Ensuring pubic safety, Stable supply of Electricity

Earthing / grounding on EETS

Regulation about grounding is classified into 4 types.(⇒next slide)

[objectives of network grounding]

- ✓ To prevent damage to the human body in case abnormal voltage occurs at the time of network fault
- ✓ To minimize damage of network facilities in case of fault
- ✓ To protect network facilities and customers' equipments in case of lightening (grounding of arresters)

Rules, Regulation for network grounding

➢ Earthing / grounding on EETS

	Condition	Regulation value	Object (e.g.)
A class	For HV or MV equipment	10[Ω]	Lightening Arrester (LA) HV equip.
B class	For Voltage rise of LV equip. by a confused MV fault contact	150/Ig[Ω](*) Ig: primary-side current of one-line ground fault	DT
C class	For LV equip. over 300V	10[Ω](*)	LV equip.
D class	For LV equip. up to 300V	100[Ω](*)	LV metallic pole Messenger wire

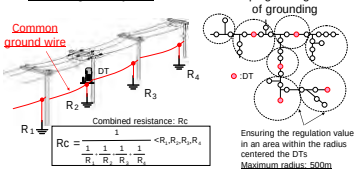
(*):These value are in TEPCO's case.
The values depend on the breaking time of network.

Regarding grounding of LA and B class grounding, **applying common ground system** is available.

Rules, Regulation for network grounding

➢ Common ground system

Grouping management of grounding



Ensuring the regulation value in an area within the radius centered the DTs
Maximum radius: 500m

Common ground system can make each resistance target high

Chapter.2 Network Grounding in Japan

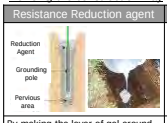
Problem and Countermeasures in Japan

Problem, Difficulties

TEPCO has mountainous & rocky area where it is difficult to get low grounding resistance. (We have the same problem as you!!)

Countermeasure (1)

➢ Devising the construction way

Resistance Reduction agent	Boring method
	
By making the layer of gel around the grounding pole, grounding resistance can be reduced. This agent reduces 50-70% of grounding resistance semipermanently.	By using special boring equipment, a grounding pole is spiked into 20m~70m depth. This method is very effective, but costs very high. (about 10,000USD)

Countermeasure (2)

➢ Proper management of grounding resistance

TEPCO measures all grounding resistance at the time of installation, and some of them regularly.

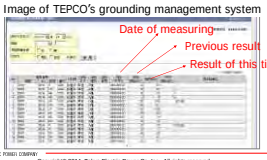
target	Period of measuring resistance
A class grounding B class grounding	• place with reduction agent - every 5 years • place where the previous measured value was more than 60% of regulation - every 5 years • the other - at any time In addition, at B class pole visual inspection is implemented every 5 years. After installing/repairing grounding, twice regular measuring must be implemented.
The other	at any time

Countermeasure (2)

TEPCO manages grounding resistance by the computer system.

This system can record the result of measuring and simulate the resistance to choose the proper way of installation.

Image of TEPCO's grounding management system



Countermeasure (3)

➢ Effort to ease the regulations

There is a third party "Japan Electric Association (JEA)" which consists in manufacturers and utilities in Japan

[JEA's role]

✓ Summary of the demand for revision of EETS

✓ Researching about electricity equipments

Electric utilities (included TEPCO) have implemented experiments about possibilities of making the regulations more rational. And they have realized that through JEA.

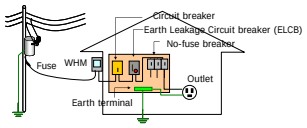
e.g. Mitigation of regulation resistance of A class grounding in the case when an arrester is in a B class grounding area

Chapter.3 In-house Grounding in Japan

In-house Grounding in Japan

Grounding system in house

Standard internal wiring in Japan



- Generally in-house earthing is separately installed (not connected to) network earthing in Japan.
- ELCB is installed in almost all new residence in Japan.(99.7%)

Chapter.4 Recommendation

Recommendation

Recommendation

✧ Network grounding

- Adoption of common grounding system
- Proper management of grounding resistance
  e.g. regularly measurement
- Use of new technology
  e.g. reduction agent

✧ In-house grounding

- Proper guidance on in-house grounding for customers
- Promoting of installing of ELCB

We recommend you above things with considering the pilot project which Begana training center has implemented.

Thank you for your attention!!

TOKYO ELECTRIC POWER COMPANY

Presentation Materials of seventh Workshop

Outline of Priority Issue Solving Activity

Issue Solving Activity

July 2014
Tokyo Electric Power Company

1

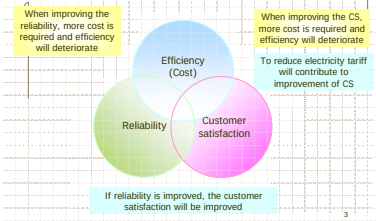
Relationship between Supplier and Customer

- In case of general products
  - Customer selects the product (supplier)
- In case of power sector
  - General customers have no choice to select their supplier
  - Most citizens have no choice but to purchase the product (electricity) with determined cost and quality
- Less incentive for power suppliers to improve the power quality or customer satisfaction

2

Major Three Factors that Power Sector shall aim

- Be gradually improved in well balance



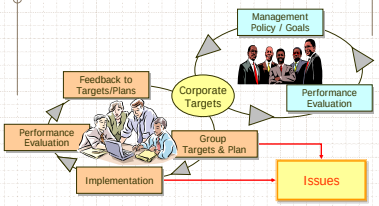
3

Opportunities to utilize TQM Activity

- Improvement of system reliability or customer satisfaction with less investment
  - There are some measures by ingenuity without so much investment.
- Efficient Investment
  - Plan with higher effect shall be prioritized
- Improvement of work efficiency
  - Spare power can be utilized to improvement of system reliability or customer satisfaction

4

Manager's Role & Responsibility



5

What is Priority Issue (PI) Solving Activity?

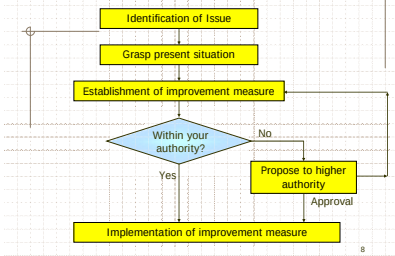
6

Objectives

- The active and proper contributions of the middle-class managers are indispensable to improving the management situations at your office.
- The main objective is to enable the middle-class managers to tackle…
  - Issues/problems to achieve their group targets / the management goals
  - Issues/problems that are significant in their working places

7

Flow of Issue Solving



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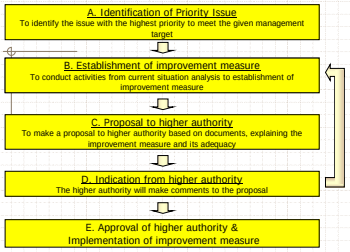


9

A. Identification of Priority Issue

- Identify a problem/issue
  - Look at things from customers' viewpoints. (if you are a customer)
  - Think about what the ideal situations are.
- Issues to be solved with top priority to realize visions of the company
  - Improvement of supply reliability, Loss reduction, Improvement of customer satisfaction, Securing of personnel safety etc. (for example)
  - Identify issue (theme) specifically

10

B. Establishment of Improvement Measure

1. Evaluation, Quantification of Current Badness
2. Cause Analysis
3. Plan out various Measures
4. Evaluation of Cost-Benefit Performance
5. Determination of Implementing Measure
6. Establishment of Implementation Plan

11

B-1. Evaluation, Quantification of Current Badness

- Use data, facts, and common words in order to describe actual phenomenon precisely in
  - understanding current situations,
  - analyzing problems, and
  - confirming impacts of measures / verifying your assumption.
- Understand things based on data, instead of judging things only on speculation or in the illusionary belief.

12

How to handle the data

- The aim of using data is to solve problems, and to make people understand easily and correctly or to appeal to people.
  - Step 1: Think about what you want to describe, analyze, confirm, verify.
  - Step 2: Think about how you should handle or show the data.

13

How to handle the data

- The use of data is to help right understandings and prevent interpersonal misunderstandings
- Data contradicting with your story should not be neglected
- Unreliable data should not be used
- Data must be gathered in consistent and sequential ways

14

B-2. Cause Analysis

- Multi-aspect cause analysis
  - To identify all considerable causes
  - Fishbone diagram
- Evaluation of significance of causes by using actual data
  - Frequency of occurrence
  - Magnitude of impact
- Refine root causes in order to require measures easily

15

B-3. Plan out Various Measures

- Measures corresponding with Causes from many aspects
  - Identify various potential solutions and measures. The solutions and measures are not only ONE.
  - Get rid of your prejudice or bias against the present situations.

16

Examples of Various Measures

- Measures with less cost
- Measures which can be conducted instantly
- Measures with large effect
- Drastic measures, even though it might take a long time and high cost.

17

B-4. Evaluation of Cost-Benefit Performance

- Evaluation of benefit
  - Expected timing of the benefit to arise
- Evaluation of cost
  - Expected timing of required payment
  - Possibility of budget procurement
- Consider time value
  - 1 Nu. (at present) ≠ 1 Nu. (1 year after)

18

B-5. Determination of Implementing Measure

- Comparison analysis & prioritization of several measures
  - Advantage/Disadvantage of application of measures
  - Cost-benefit performance
  - Difficulty
  - Amount of required resource to be injected
  - Timing when implementation is possible
  - Secondary (indirect) effects

19

B-6. Establishment of Implementation Plan

- Resource to be injected
  - Budget, manpower
- Timing and schedule of implementation
- Expected effect
- Other items to be considered
  - Confirm that any other problem will not occur by taking a solution/measure to be selected.
  - Have a viewpoint that a selected solution and measure will have large impacts if it is shared with other people. (lateral spreading)

20

C. Proposal to Higher Authority

- Preparation of presentation material
  - Easily understandable explanation
    - Easily understandable logic
    - Straightforward storyline
    - Short-time, limited main points
  - Easy-to-read documents
    - Effective use of figures & tables
    - What is the key message from figures/tables

21

When you carry out **PI Solving Activity**, Repeat **Self-Questionings** to achieve good performance

1. Are there still any other causes that result in badness?
2. Are there any alternative solutions, that you have not yet found out?
3. Did you compare solutions well enough in light of cost and effectiveness?
4. Did you prepare multiple solutions and analyze them well enough, so that your boss can compare and judge with your proposal?

22

Issue Solving Activity

- Work should not always be done only by yourself
  - Instructing Junior Staffs for Information gathering
  - Brain storming with other managers/officers
  - Discussion with higher authority
- Not special work (Routine work)
  - Always consider to improve current situation
- Make story and logic to convince higher authority using data & facts

23

Issue Solving Activity

- Not only beneficial for the company, but also for you
  - Save time
    - Family benefit; Enjoy private time
  - Save money
    - Money benefit; Increasing your wage
- Don't give up solving problems or issues.
  - There are many measures

24

QC Tools

Data Management and TQM Tools

July 2014

Tokyo Electric Power Company (TEPCO)

1

Contents

2

1. Significance of Data Management

3

Why *Data Management* is significant?

Data is necessary from viewpoints …

1. Survey actual conditions and Analyze phenomena

2. Establish Action Policies and Do Decision-making reasonably

3. Check the proceedings and Control the direction

4

Quality Management must be based on Facts

Bad Management
- based on **Experiences**, **Intuitions**
- impossible to reach Corporate Target

Good Management
- based on **Facts** (**Data**, **Actual Results**, **Information** or **Common words**)
- possible to reach Corporate Target

5

Advantages of Data Management

- Data Management enables you to quantify the Quality.
- Quantification helps you to deliver the information accurately to others.
- Quantification helps you to easily share problems and avoid others' subjectivities.
- Proposals established on Data have the power of persuasion.

6

2. Items of Useful TQM Tools

7

What are the TQM Tools?

1. TQM Tools are **techniques** applied in quality management activities.
2. They are applied in order to **identify problems**, compile information, get ideas, **analyze factors**, **devise solutions to problems**.
3. **Using the TQM Tools is not a Goal**. They just help us understand the problems.

8

TQM Tools (7 Tools)

- Pareto Diagrams
- Cause & Effect Diagrams
- Graphs
- Check Sheets
- Histograms
- Scatter Diagrams
- Control Charts

9

7 Tools

	Name	Purpose	Characteristics & Image
1	Pareto Diagrams	Select the Priority Issues. Grasp the importance of each item.	Bar charts of each item. Line plot of accumulated values
2	Cause and Effect Diagrams	Pursue the cause of the problem. Sort out the knowledge of causes and effects.	Final effect is linked by the associated causes.
3	Graphs	Facilitate to grasp the information of data through visualization.	Circular graph, Bar chart, Radar chart
4	Check Sheets	Facilitate the data collection and the data sorting.	Spreadsheet or records for easy data collecting and less-mistakable format.

10

7 Tools

	Name	Purpose	Characteristics & Image
5	Histograms	Grasp the data dispersion. Grasp the characteristics of distribution.	Bar charts of the frequency distribution table.
6	Scatter Diagrams	See the co-relation between two parameters. Study co-relation and recurrence.	Plot diagram of two parameters, each of which is allotted to X-axis and Y-axis.
7	Control charts	Facilitate to grasp the information of data through visualization. Manage the process. Analyze the problem in the process.	Line plot dependent on time, with regulated limits' lines.

11

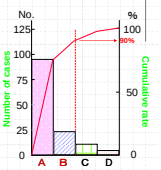
① Pareto Diagrams

- ❑ **Purpose is to find out dominant factors of the problems**

Example

"System Loss data"

Group	System Loss item	No. of cases	Cumulative No.	Cumulative %
A	Transformer Unbalance	90	90	72%
B	Power Theft	22	112	90%
C	Stopped Meters	10	122	98%
D	Loose connection	3	125	100%
	Total	125		



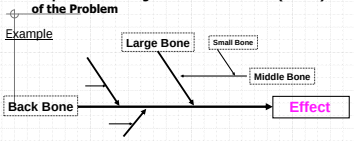
- ❑ **Put Simple Bar diagram in descending order, and draw a cumulative line plot**
- ❑ **Easy to grasp the "dominant factors" of the problem**

12

② Cause & Effect Diagrams

- ❑ **Purpose is to arrange "Causes" & "Effect (Result)" of the Problem**

Example



- ❑ **Write " Effect (Result) " on the right side of a "Back Bone"**
- ❑ **Write classification of "Causes" at the end of "Large Bones"**
- ❑ **Write "Causes" into "Middle" & "Small Bones"**

13

② Cause & Effect Diagrams

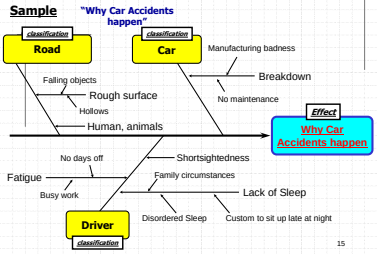
Points to Remember when constructing Diagrams

- ❑ **Brain storming session is a principle rules to list up "Causes"**
- ❑ **"Group thinking" is more effective than "Individual thinking"**
- ❑ **Repeat "Why" over and over again with all Participants**
- ❑ **Use as few words as possible**
- ❑ **Reach a team consensus**

14

② Cause & Effect Diagrams

Sample

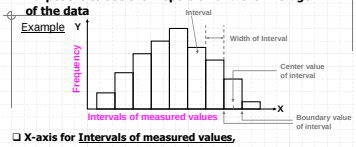


15

③ Histograms

- ❑ **Purpose is to see the Dispersion and the Average of the data**

Example



- ❑ **X-axis for Intervals of measured values, Y-axis for Frequency within each intervals**
- ❑ **Histograms give information as below;**
  - **(1) Center of the Data (2) Amplitude of dispersion**
  - **(3) Shape of distribution**
  - **(4) Existence or non-existence of Abnormality**
  - **(5) Deviation from the Standard Ranges**

16

③ Histograms

How to Construct a Histogram

- ❑ **Step 1: Collect Data**
- ❑ **Step 2: Find Maximum and Minimum of Data**
  - **Arrange data in the Matrix style**
  - **Find Maximum and Minimum value in each column (row)**
  - **Find the Grand Max. and Min. from the marked values**

Dimensions of Products A [mm]

45.1	47.1	45.6	X 45.2	O 47.7	45.8	O 46.8	45.4	X 45.0	45.1
46.2	46.8	45.1	45.6	45.5	45.7	46.2	44.9	45.2	45.6
45.3	O 47.6	45.8	46.0	X 45.1	OO 48.0	46.1	45.4	O 47.3	45.2
45.8	45.7	O 46.1	46.4	45.3	45.7	46.7	O 46.8	45.2	O 45.7
45.7	46.8	45.9	O 47.5	45.8	45.9	46.6	46.1	45.6	X 44.5
O 46.9	45.7	45.2	46.7	47.5	46.0	45.7	46.5	45.7	45.5
44.5	X 45.2	45.3	45.5	47.3	46.1	45.9	46.1	45.5	44.6
44.6	45.3	45.7	X 45.2	45.7	45.3	X 44.8	X 44.2	45.1	45.0
XX 43.9	46.0	45.8	45.3	45.9	44.9	45.1	45.0	X 45.0	45.1
44.8	45.5	X 45.0	45.8	45.7	X 44.8	45.2	45.4	45.2	45.4

O: Maximum value of each column, X:Minimum value of each column

17

③ Histograms

Example to Construct a Histogram

- ❑ **Step 3: Make up a Frequency Table**

No.	Boundary of Interval	Center of Interval	Tick	Frequency
1	43.85 – 44.25	44.05	//	2
2	44.25 – 44.65	44.45	////	4
3	44.65 – 45.05	44.85	//// ////	10
4	45.05 – 45.45	45.25	//// //// //// //// /	26
5	45.45 – 45.85	45.65	//// //// //// //// /	26
6	45.85 – 46.25	46.05	//// //// ////	14
7	46.25 – 46.65	46.45	///	3
8	46.65 – 47.05	46.85	//// //	7
9	47.05 – 47.45	47.25	///	3
10	47.45 – 47.85	47.65	////	4
11	47.85 – 48.25	48.05	/	1
			Total	100

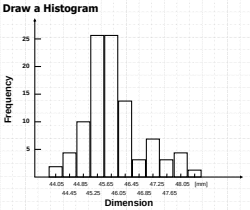
Example : Width of Interval = 0.4 mm

18

③ Histograms

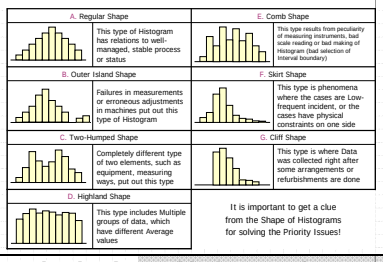
Example to Construct a Histogram

- ❑ **Step 4: Draw a Histogram**



19

③ Histograms



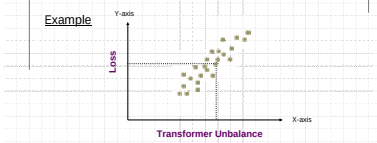
It is important to get a clue from the Shape of Histograms for solving the Priority Issues!

20

④ Scatter Diagrams

- ❑**Purpose is to examine the relationship between two variables**

Example



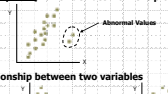
- ❑**Plot the points where X & Y intersects**

21

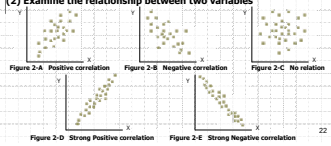
④ Scatter Diagrams

Estimation of Scatter Diagrams

(1) Examine Abnormal points, which deviate from the plotted group



(2) Examine the relationship between two variables



22

Tool Selection Guide for 7 Tools

No.	Sequence of procedure \ Tool	Graph	Control chart	Pareto Chart	Histo-gram	Cause-effect diagram	Scatter-ed diagram	Check sheet
1	Identification of issue	◎ Bar chart, line graph	○	●	○	◉		○
2	Understanding of the present status and goal setting	● Bar chart, line graph	○	◉	◉	○	○	●
3	Preparation of action plan	● Gantt Chart						
4	Analysis of element	● Bar chart, line graph	◉	○	●	●	●	●
5	Study on and implementation of the countermeasure	◉				●		
6	Confirmation of the effect	◉ Bar chart, line graph	●	◉	●		○	○
7	Standardization and establishment of control	○	●		○			●

24

Thank you for your attention

Exercise: QC Tools - Basic of Statistics

JICA Technical Cooperation Project
Improvement of Efficiency for Rural Power Supply Phase II

Lecturer

Exercise : QC Tools
- Basic of Statistics -

July 2014
Tokyo Electric Power Co.

4

Lecture

Table of Contents

5

Lecture

1. Items of Useful TQM Tools

6

Lecture

What are the TQM Tools?

1. TQM Tools are **techniques** applied in quality management activities.
2. They are applied in order to **identify problems**, compile information, get ideas, **analyze factors**, **devise solutions to problems**.
3. **Using the TQM Tools is not a Goal**. They just help us understand the problems.

7

Lecture

TQM Tools

7 Tools

- Pareto Diagrams
- Cause & Effect Diagrams
- Graphs
- Check Sheets
- ✓Histograms
- ✓ Scatter Diagrams
- ✓ Control Charts

Numeric Data Analysis

8

Lecture

7 Tools

Name	Purpose	Characteristics & Image
Pareto Diagrams	**Select the Priority Issues. Grasp the importance of each item.**	Bar charts of each item. Line plot of accumulated values
Cause and Effect Diagrams	**Pursue the cause of the problem. Sort out the knowledge of causes and effects.**	Final effect is linked by the associated causes.
Graphs	**Facilitate to grasp the information of data through visualization.**	Circular graph, Bar chart, Radar chart
Check Sheets	**Facilitate the data collection and the data sorting.**	Spreadsheet or records for easy data collecting and less-mistakable format.
Histograms	**Grasp the data dispersion. Grasp the characteristics of distribution.**	Bar charts of the frequency distribution table.
Scatter Diagrams	**See the correlation between two parameters. Study correlation and regression.**	Plot diagram of two parameters, each of which is allotted to X-axis and Y-axis.
Control charts	**Facilitate to grasp the information of data through visualization. Manage the process. Analyze the problem in the process.**	Line plot dependent on time, with regulated limits' lines.

Lecture

2. Exercise :Histograms

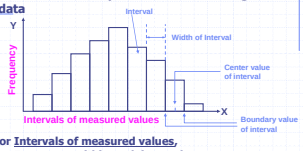
10

Lecture

① Histograms

❑ **Purpose is to see the Dispersion and the Average of the data**

Example



❑ **X-axis for Intervals of measured values, Y-axis for Frequency within each intervals**
❑ **Histograms give information as below;**
(1) Center of the Data
(2) Amplitude of dispersion
(3) Shape of distribution
(4) Existence or non-existence of Abnormality

11

Question

Exercise 1 Making histogram (1)

Make a histogram and explain your graph to your audience.

- 20 Men's heights (raw data)

No.	Heights (cm)	No.	Heights (cm)
1	158	11	166
2	163	12	154
3	139	13	165
4	157	14	148
5	156	15	172
6	144	16	156
7	152	17	162
8	176	18	167
9	154	19	181
10	149	20	159

Hints
- Min, and Max
- Class interval (10cm)
- Mid point
- Tally
- Frequency
- Relative frequency

12

Question

Exercise 1 Making histogram (1)

Make a histogram and explain your graph to your audience.

Max=__, Min=__, Range=Max-Min=__-__=__cm
Class interval=10cm

Class No	Class intervals	Midpoint	Frequency	Relative Frequency	Accumulative Frequency
1	130-140				
2	140-150				
3	150-160				
4	160-170				
5	170-180				
6	180-190				
Total					

13

Question

Exercise 1 Making histogram (2)

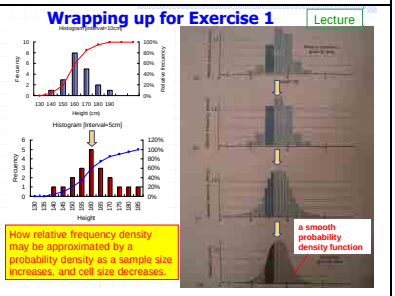
When class interval changes to 5cm from 10cm, make a histogram.

Class No	Class intervals	Midpoint	Frequency	Relative Frequency	Accumulative Frequency
1	135-140				
2	140-145				
3	145-150				
4	150-155				
5	155-160				
6	160-165				
7	165-170				
8	170-175				
9	175-180				
10	180-185				
Total					

14

Lecture

Wrapping up for Exercise 1



How relative frequency density may be approximated by a probability density as a sample size increases, and cell size decreases.

Lecture

Spread of Distribution

■**Variance**

❑Variance: $\sigma'^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$

❑Standard deviation : σ'

❑Coefficient of variation: $C = \sigma' / \bar{x}$

Above the distribution (or data), mean, median, and mode are same, but different spread of distribution.

16

Lecture

Spread of Distribution

■**Variance**

❑Variance: $\sigma'^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$

A random variable, probability distribution, or sample is a measure of statistical dispersion, averaging the squared distance of its possible values from the expected value (mean). Whereas the mean is a way to describe the location of a distribution, the variance is a way to capture its scale or degree of being spread out.

❑Standard deviation : σ'

A measure of the variability or dispersion of a population, a data set, or a probability distribution. A low standard deviation indicates that the data points tend to be very close to the same value (the mean), while high standard deviation indicates that the data are "spread out" over a large range of values.

❑Coefficient of variation: $C = \sigma' / \bar{x}$

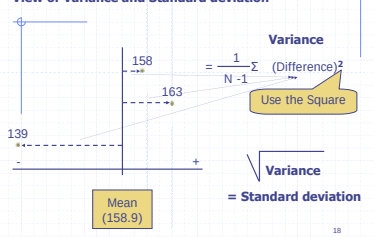
A normalized measure of dispersion of a probability distribution. It is defined as the ratio of the standard deviation to the mean.

17

Lecture

Spread of Distribution

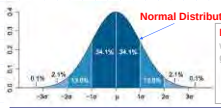
View of Variance and Standard deviation



18

Spread of Distribution

Lecture



Probability density function
which is the formula for the general normal distribution.

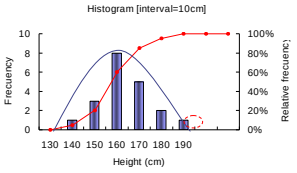
$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

To understand standard deviation, keep in mind that variance is the *average* of the squared differences between data points and the mean. Variance is tabulated in units squared. Standard deviation, being the square root of that quantity, therefore measures the spread of data about the mean, measured in the same units as the data.

For the normal distribution, this accounts for **68.27 %** of the set; while two standard deviations from the mean (medium and dark blue) account for **95.45 %**; three standard deviations (light, medium, and dark blue) account for **99.73 %**; and four standard deviations account for 99.994 %.

Spread of Distribution

Lecture



20

Exercise 2 Variance (Spread of Distribution)

Question

(a) Calculate mean, variance, and standard deviation

(b) Find out abnormal (extraordinary) value

No.	Heights (cm)	No.	Heights (cm)
1	158	11	166
2	163	12	154
3	139	13	165
4	157	14	148
5	156	15	172
6	144	16	156
7	152	17	162
8	176	18	167
9	154	19	181
10	149	20	159

Variance $\sigma'^2 = \frac{1}{n-1}\sum(x_i - \bar{x})^2$

Standard deviation : σ'

21

3. Exercise : Scatter Diagrams

Lecture

22

② Scatter Diagrams

Lecture

- Purpose is to examine the relationship between two variables

Example

- Plot the points where X & Y intersects

23

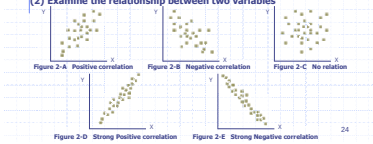
② Scatter Diagrams

Lecture

Estimation of Scatter Diagrams

(1) Examine Abnormal points, which deviates from the plotted group

(2) Examine the relationship between two variables

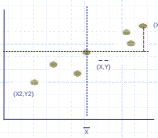


24

Correlation coefficient

Lecture

Covariance



$$\frac{1}{N-1}\Sigma\ (X_i-\bar{X})\ (Y_i-\bar{Y})$$

\+ \+ / - -

\+ Positive correlation

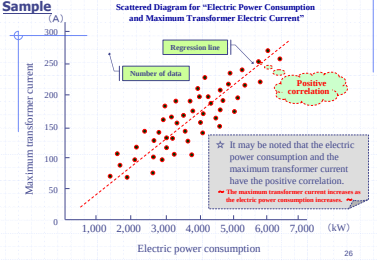
\- Negative correlation

25

② Scatter Diagrams

Lecture

Sample



26

Correlation coefficient

Lecture

$$\frac{1}{N-1}\Sigma\ (X_i-\bar{X})\ (Y_i-\bar{Y})$$

$$r^2 = \frac{(\Sigma\ X_i Y_i - n \cdot Xmean \cdot Ymean)^2}{(\Sigma\ X_i^2 - n \cdot Xmean^2) \cdot (\Sigma\ Y_i^2 - n \cdot Ymean^2)}$$

Coefficient of Correlation $r = \sqrt{r^2}$

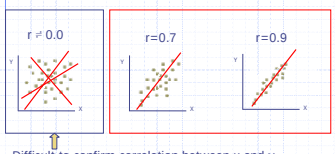
27

Scatter Diagrams

Lecture

What is Coefficient of Correlation r

There is correlation



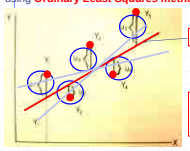
Difficult to confirm correlation between x and y

28

Regression Analysis
Ordinary Least Squares method (OLS)

Lecture

Regression Analysis is a technique used for the modeling and analysis of numerical data consisting of values of a dependent variable (response variable) and of one or more independent variables (explanatory variables). The dependent variable in the *regression equation* is modeled as a function of the independent variables, corresponding parameters ("constants"), and an *error term*. The parameters are estimated so as to give a "best fit" of the data. Most commonly the best fit is evaluated by using **Ordinary Least Squares method (OLS)**.



Regression Equation

$$Y = a + b\,X + e$$

Best fit regression equation is determined when sum of error terms is the least. This is OLS.

29

Deviation of the Regression Equation

Lecture

Use the Square

$$Y = a + b\,X + e \rightarrow e = Y - a - b\,X \rightarrow e^2 = \Sigma\ (Y - a - b\,X)^2$$

Differentiate

times Σ X

$$\frac{\partial}{\partial a}\Sigma\ (Y - a - b\,X)^2 = \Sigma\ -2\ (Y - a - b\,X) = 0 \rightarrow \Sigma\ Y - na - b\Sigma\ X = 0$$

$$\frac{\partial}{\partial b}\Sigma\ (Y - a - b\,X)^2 = \Sigma\ -2X(Y - a - bX) = 0 \rightarrow \Sigma\ XY - a\Sigma\ X - b\Sigma\ X = 0$$

times n

$$a = (\Sigma\ Y - b\Sigma\ X)/n$$

$$a = Ymean - b \cdot Xmean$$

$$\Sigma\ X\Sigma\ Y - b(\Sigma\ X)^2 - n\Sigma\ XY + nb\Sigma\ X^2 = 0$$

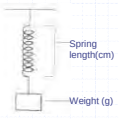
$$b = \frac{\Sigma\ X\Sigma Yi - n \cdot Xmean \cdot Ymean}{\Sigma\ Xi^2 - n \cdot Xmean^2}$$

Exercise 3a (Regression Analysis)

Question

Calculate Regression Equation, and Coefficient of Correlation

No.	X	Y
	Wight (g)	Spring length (cm)
1	5	13
2	10	14
3	15	18
4	20	19
5	25	22
6	30	26



31

Exercise 3b (Regression Analysis)

Question

(1) Any correlation between Load factor and transformer temp?

(2) What is prediction of temperature when load factor is 100%?

32

4. Exercise : Control Charts

Lecture

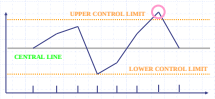
33

③ Control Charts

Lecture

- Purpose is to see whether the conditions are in preferable status or not

Example



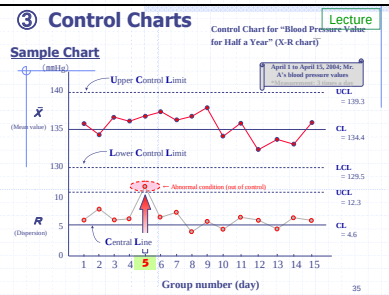
- UCL (Upper Control Limit) & LCL (Lower Control Limit) are statistically determined on either side of Center Line
- No abnormality in dispersion, then condition is STABLE
- If points are outside limits – indicates unusual causes

34

③ Control Charts

Lecture

Sample Chart



35

Exercise 4 (Control Charts)

Question

Make Data Analysis and find out the extraordinary phenomenon to prevent major accident.

Standard Deviation = 2

36

Lecture

5. Attention

37

Lecture

When you carry out **PI Solving Activity**,
Repeat **self-questionings** to achieve good performance

1. Are there still any other Causes that result in Badness?
2. Are there still any Alternative Solutions, that you have not yet found out?
3. Did you compare Solutions well enough in light of Cost and Effectiveness?
4. Did you prepare multiple Solutions and analyze them well enough so that your Boss can compare and judge with your proposals?

38

Lecture

The points are as below, when you wrap up your Achievement Report

- Quantitative description of your Issue
- Quantitative Verification of Adequacy of your proposed countermeasure
- Cost-effect comparison among several Countermeasures

39

Basic of Economic Analysis

JICA Technical Cooperation Project
Improvement of Efficiency for Rural Power Supply Phase II

Basic of Economic Analysis

July 2014
Tokyo Electric Power Co.

1

Lecture

Table of Contents

2

Lecture

Review of PI Solving Activity

A. Selection of Study Theme
To select the issue with the highest priority to meet the given management target

B. Establishment of improvement measures
To conduct activities from current situation analysis to establishment of improvement measures

C. Proposal to management class
To make a presentation to the management class based on documents, explaining the improvement measure and its adequacy

D. Indication from the management class
The management class will make comments to the proposal

E. Approval of management class & Implementation of improvement measure

3

Lecture

Review of PI Solving Activity

B. Establishment of Improvement Measures

1. Evaluation, Quantification of Current Badness
2. Cause Analysis
3. Establishment of Countermeasure Plans
4. Evaluation of Cost-Benefit Performance
5. Determination of Implementing Countermeasure

Lecture

Review of PI Solving Activity

4. Evaluation of Cost-Benefit Performance
(or Cost-effectiveness, Investment efficiency)

Economic analysis is an important tool for decision-making

5

Lecture

Introduction of Evaluating Methods

- When evaluating the economic efficiency among several countermeasure plans (or projects), the most commonly used methods (indicators) are: ROI, Payback Period, NPV and IRR.
- Both NPV and IRR are better techniques than ROI and Payback, because NPV and IRR favor long-term, and hence more risky projects that power utilities like BPC should be doing.

6

Lecture

Introduction of Evaluating Methods

Comparison of major methods

	Time value of money	Life-cycle cash flows	Risk considerations	Easy to understand
Return on Investment (ROI)	No	No	No	**Yes**
Simple Payback Period (SPP)	No	No	No	**Yes**
Net Present Value (NPV)	**Yes**	**Yes**	**Yes**	No
Internal Rate of Return (IRR)	**Yes**	**Yes**	**Yes**	No

7

Lecture

1. Return on Investment (ROI)

- Return on Investment (ROI) is the ratio of money gained on an investment relative to the amount of money invested.
- ROI refers to the rate of the profit against the amount of investment. It is thus usually given as a percent value.
- ROI = Return from investment / Cost of investment

8

Lecture

1. Return on Investment (ROI)

- For instance, a $1,000 investment that earns $50 per year generates more return than a $100 investment that earns $20. However, the $100 investment earns a higher ROI.

$50 / $1,000 = 5% ROI
$20 / $100 = 20% ROI

9

Lecture

1. Feature of ROI

Criteria	◆How profitable an investment is . ◆Higher ROI is preferable to lower ROI.
Advantages	◆Easy to understand ◆Simple calculation
Disadvantages	◆Time value of money (interest rate and risks) is not considered. ◆Does not indicate how long an investment is held. Indicates an annualized rate of return.

10

Lecture

Topic: Cash Flow (CF)

- Cash flow is a measure of cash inflow and outflow which generate from a income-generating project.
- Net cash flow refers to the excess of cash inflows over cash outflows (the amount of remaining money) in a given operation or a certain period of time.
- It is a measure of economic efficiency but does not coincide with the accounting term "profit".
- The table below is an example of cash flow statement:

Year	0	1	2	3	4	5	6
Investments	-$200mil.						
O&M Cost		-$20mil.	-$20mil.	-$20mil.	-$20mil.	-$20mil.	-$20mil.
Expected Revenue		$80mil.	$80mil.	$80mil.	$80mil.	$80mil.	$80mil.
Net cash flow at each year	-$200mil.	$60mil.	$60mil.	$60mil.	$60mil.	$60mil.	$60mil.

11

Question

Exercise (ROI)

Net cash flow on $1,000 investment

Year	0	1	2	3	4	5
Net Cash flow	-$1,000	$100	$90	$80	$50	$40

Calculate the ROI of each year:

Year	0	1	2	3	4	5
ROI	-	10%	9%	8%	5%	4%

12

Lecture

2. Simple Payback Period (SPP)

- Payback period (PP) refers to the period of time required for the return on an investment to "repay" the sum of the original investment.
- For example, a $1,000 investment which returned $500 per year would have a two year payback period.

13

Lecture

2. Feature of SPP

Criteria	How long it takes to pay for itself. Shorter payback period is preferable to longer payback period.
Advantages	Easy to understand. Simple calculation.
Disadvantages	Time value of money (interest rate and risks) is not considered. Ignores the cash flow after payback period.

14

Question

Exercise (SPP)

How long is the payback period?

Year	0	1	2	3
Net cash flow	- $3,000	+$1,500	+$1,000	+$1,000

3,000 = 1,500 + 1,000 + 500

➔ 2.5 years

15

Lecture

Time Value of Money

- Congratulations! You have won a cash prize. You have two options:

  Option A. Receive $10,000 now

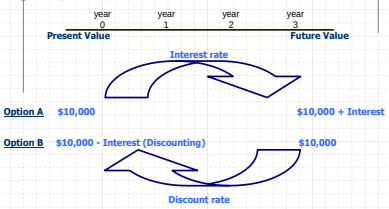
  Option B. Receive $10,000 three years later.
- You would choose to receive the $10,000 now. It is better to have it now rather than later. But why?
- Actually, although the amount is the same, you can do much more with the money if you have it now: over time you can earn more interest on your money.

16

Lecture

Time Value of Money

Image of Option A and B



17

Lecture

Time Value of Money (FV)

- For example,
  - Present value: $10,000
  - Interest rate: 10% per year
  - Future value (FV) becomes $11,000 (1 year later)

Present $10,000 = Future $11,000 (1 year later)

18

Question

Exercise (FV)

If you choose option A and invest the total amount at a annual rate of 10%, calculate the future value.

After 1 year : $10,000 x (1+10%) = $11,000

After 2 years: $11,000 x (1+10%) = $12,100

After 3 years: $12,100 x (1+10%) = $13,310

$10,000 x $(1+10\%)^3$ ➔ $13,310

Future Value = Cash x (1+Interest rate) No. years

$FV = Cash \cdot (1+r)^n$

19

Question

Exercise (FV for each Interest Rate)

Future value of $1 'n' year(s) later = 1 x $(1+r)^n$

	Interest rate (%)		
n	5%	7%	10%
1	1.050	1.070	1.100
2	1.103	1.145	1.210
3	1.158	1.225	1.331
4	1.216	1.311	1.464
5	1.276	1.403	1.611
6	1.340	1.501	1.772
7	1.407	1.606	1.949

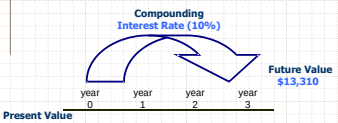
Assuming interest rate of 10%, what's the future value of $100 at year 7 (seven) ? ➔ $194.9

20

Lecture

Time Value of Money (FV)

Image of Option A



21

Lecture

Time Value of Money (PV)

- Present value (PV) is the current worth of a future money, discounted to reflect the time value of money by using a specified rate of return.
- Future money is discounted at the discount rate. The higher the discount rate, the lower the present value of the future money.
- Receiving $10,000 now (A) is worth more than $10,000 three years from now (B), because if you had the money now, you could invest it and receive an additional return over the three years.

22

Lecture

Time Value of Money (PV)

- For example,
  - Future value (1 year later): $11,000
  - Discount rate: 10% per year
  - Present value becomes $10,000

Future $11,000 (1 year later) = Present $10,000

23

Question

Exercise (PV)

If you choose option B with a discount rate of 10%, calculate the Present Value.

After 1 year : $10,000 / (1+10%) = $9,091

After 2 years: $10,000 / $(1+10\%)^2$ = $8,264

After 3 years: $10,000 / $(1+10\%)^3$ ➔ $7,513

Present Value = Cash / (1+Discount rate) No. years

$PV = Cash / (1+i)^n$

24

Question

Exercise (Discount Rate)

Present value of $1 'n' year(s) later = 1 / $(1+r)^n$

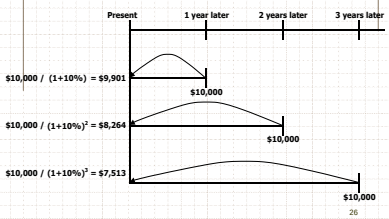
	Discount rate (%)		
n	5%	7%	10%
1	0.952	0.935	0.909
2	0.907	0.873	0.826
3	0.864	0.816	0.751
4	0.823	0.763	0.683
5	0.784	0.713	0.621
6	0.746	0.666	0.564
7	0.711	0.623	0.513

Assuming discount rate of 10%, what's the present value of $100 at year 7 (seven) ? ➔ $51.3

25

Lecture

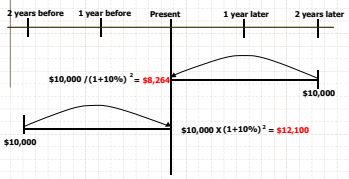
Time Value of Money (PV)



26

Lecture

Time Value of Money (PV)

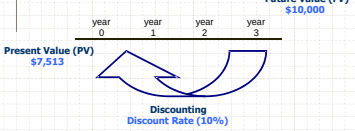


27

Lecture

Time Value of Money (PV)

Image of Option B



28

Lecture

Life-Cycle Cash Flow (LCC)

- Life-cycle cash flow (LCC) is an analysis of the total cash flow of an investment plan or project over its service life, allowing a comprehensive assessment of anticipated cash flow associated with the plan or project.
- Factors commonly considered in LCC analysis are initial investment, sales incomes, O&M costs, financing costs and expected life of project.

29

Question

Exercise (LCC)

- For example,
  - Construction : $300M
  - Electricity Sales : $80M
  - O&M : $20M
  - Life-cycle : 7 years

Calculate net cash flow of each year on the table below:

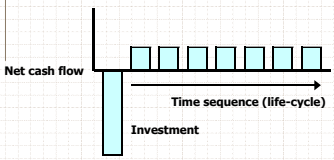
Year	0	1	2	3	4	5	6	7
Investment	300	0	0	0	0	0	0	0
Sales	0	80	80	80	80	80	80	80
O&M	0	20	20	20	20	20	20	20
Net cash flow	-300	60	60	60	60	60	60	60

30

Lecture

Life-Cycle Cash Flow (LCC)

Cash flow diagram of the said example



31

Lecture

Risk Consideration

- Risk is inseparable from return. Every investment involves some degree of risk.

	Present	Year 1	Year 2	Year 3	
Plan 1	-$1,000mil.	$105mil.	$95mil.	$100mil.	Not Risky
Plan 2	-$1,000mil.	$50mil.	$180mil.	$70mil.	Risky
Plan 3	-$1,000mil.	$0mil.	$250mil.	$50mil.	Too Risky

Net cash flow

- Risk is the possibility of a return being more different than expected.

32

Lecture

Topic: Discount Cash Flow (DCF) Analysis

- For power utilities, the investment efficiency evaluation (IEE) requires a long-term viewpoint, taking into account the life-cycle cash flow of projects or investments, which is inevitably accompanied by the time value of money and some degree of risks.
- Discounted cash flow (DCF) analysis is the one that takes into consideration all of the above three concerns. The DCF analysis consists of two methods: NPV and IRR.
- The process of investment decision-making by using DCF analysis is as follows:

1. All future cash flow (Life-cycle cash flow) → 2. Convert to PV with discount rate (Time value & Risks) → 3. Calculation (NPV or IRR)

- DCF analysis is widely used for power utilities to evaluate the economic efficiency of long-term investment.

33

Lecture

Topic: How to Set a Discount Rate?

- Theoretical definition of discount rate are:
  - Expected rate of return for investments
  - Time value of money + Risk-considered return
  - Cost of capital (financing cost for investments)
- In practice, we can appropriately set a discount rate by referring to:
  1) Interest rate charged by a Central Bank on a loan to a member bank (What is Bhutan's rate?).
  2) Interest rate of short-term Government bond distributing in the country.

34

Lecture

3. Net Present Value (NPV)

- Net Present Value (NPV) is the standard method for profitability analysis of long-term projects or investments.
- NPV refers to the present value of expected future cash flows (inflows), minus cash outflows (initial investment).
- Time value of money is taken into consideration by setting a certain discount rate.

35

Lecture

3. Feature of NPV

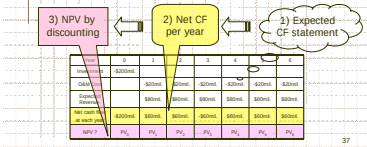
Criteria	NPV > 0 : Acceptable NPV < 0 : Not acceptable The larger the NPV, the better the project.
Advantages	Can be applied to compare two or more mutually exclusive projects. Takes into consideration the scale of investments.
Disadvantages	Setting a discount rate is difficult.

36

Lecture

3. Steps in Calculating NPV

1) Calculation of expected cash inflows and out flows
2) Calculate the net cash flow per year
3) Convert each cash flow by using discount rate, then summate each of obtained present value



37

Lecture

3. Formula of NPV

Net CF	CF_0	CF_1	CF_2	CF_3	••••	CF_n

$$NPV = CF_0 + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \frac{CF_3}{(1+i)^3} + \bullet\bullet\bullet\bullet + \frac{CF_n}{(1+i)^n}$$

NPV	PV_0	PV_1	PV_2	PV_3	••••	PV_n

Where
i : Discount rate
CF_n: Net cash flow at year "n"
Net CF_n= $(\text{Cash inflow})_n$ - $(\text{Cash outflow})_n$

38

Question

3. Exercise (NPV)

Cash flow statement of an investment project, with a life-cycle of 3 years.

Year	0 (CF_0)	1(CF_1)	2(CF_2)	3(CF_3)
Net cash flow	-$5,000	+$2,000	+$2,000	+2,000

If the discount rate is 5%, calculate the NPV.

$$NPV = -\$5{,}000 + \frac{\$2{,}000}{(1+5\%)} + \frac{\$2{,}000}{(1+5\%)^2} + \frac{\$2{,}000}{(1+5\%)^3}$$

➔ $446 (NPV is positive : the project is acceptable)

39

Question

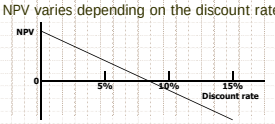
3. Exercise (NPV) Cont.

If the discount rate is 10%, the NPV will be…

$$NPV = -\$5{,}000 + \frac{\$2{,}000}{(1+10\%)} + \frac{\$2{,}000}{(1+10\%)^2} + \frac{\$2{,}000}{(1+10\%)^3}$$

➔ -$26 (NPV is negative : the project is not acceptable)

NPV varies depending on the discount rate.

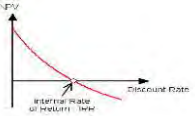


40

Lecture

4. Internal Rate of Return (IRR)

- Internal rate of return (IRR) refers to the discount rate at which the NPV is zero.



- A hurdle rate, the minimum required IRR that must be met to undertake a particular project, is set as the benchmark rate.
- If IRR is higher than a hurdle rate, a sort of go/no-go threshold (often same as capital cost or market interest rate), the investment may be accepted.

41

Lecture

4. Feature of IRR

Criteria	IRR > Hurdle rate : Acceptable IRR < Hurdle rate : Not acceptable The higher the IRR, the more profitable the project.
Advantages	Profitability can be easily ranked in terms of rate of return.
Disadvantages	Scale of investment/project is not considered.

42

Question

4. Exercise (IRR)

Year	Expected Cash flow	Present Value		
		i = 6%	i = 8%	i = 10%
0	- $1,000	- $1,000	- $1,000	- $1,000
1	$300	$283	$278	$273
2	$200	$180	$171	$165
3	$200	$168	$159	$150
4	$350	$277	$257	$239
5	$200	$149	$136	$124
NPV	+ $250	+ $57	+ $1	- $49

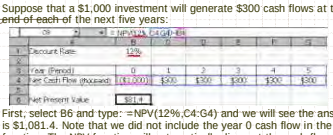
What is the IRR? ➔ IRR= 8%

43

Lecture

Topic: Microsoft Excel Functions – NPV

- Suppose that a $1,000 investment will generate $300 cash flows at the end of each of the next five years:



- First, select B6 and type: =NPV(12%,C4:G4) and we will see the answer is $1,081.4. Note that we did not include the year 0 cash flow in the function. The NPV function will automatically discount the cash flow of year 0, even if it shouldn't.
- Second, remember that the NPV, according to the actual definition, is calculated as the present value of the expected future cash flows, minus the cost of the investment.
- Then, we need to subtract the $1,000 of the investment. Therefore, the formula to calculate the net present value is: =NPV(B1,C4:G4)-B4 and the answer is $81.4.

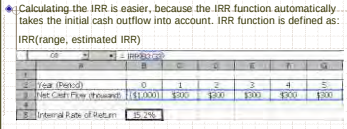
44

Lecture

Topic: Microsoft Excel Functions – IRR

- Calculating the IRR is easier, because the IRR function automatically takes the initial cash outflow into account. IRR function is defined as:

IRR(range, estimated IRR)



- Note that the "range" is a series of net cash flows, including the initial investment. The "estimated IRR" is optional and generally isn't needed. Thus the function in B6 is: =IRR(B3:B3).
- As seen above, the answer is 15.2%. This means that if we implement the investment for $1,000 now, the compound average annual rate of return will be 15.2% per year.

45

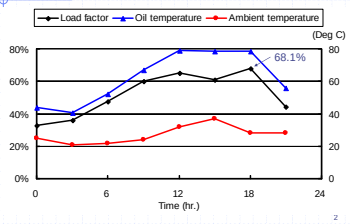
Data Management

Data Management

July 2014

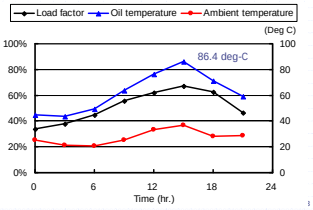
1

Maximum Load Factor: 68.1% (18th-June 18:00)



2

Maximum Oil Temp.: 86.4 deg-C (17th-June 15:00)



3

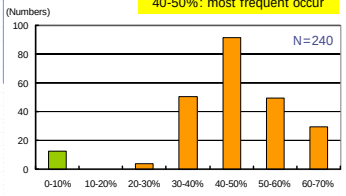
Information

- Maximum load factor: 68.1%
  - 18th-June 18:00
- Maximum oil temperature: 86.4 deg-C
  - Less than limit (90 deg-C)
  - 17th-June 15:00
- Peak hours: 12:00 - 18:00
- Off-Peak hours: 00:00 - 06:00

4

Histogram of Load Factor

40-50%: most frequent occur



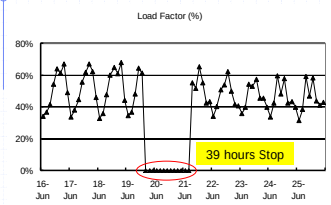
5

Information

- Average load factor: 44.9%
- Mode: 40% - 50%
- Minimum load factor: 26.6% (except stop)
  - 30th-June 00:00

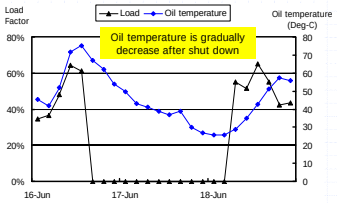
6

Outage



7

Load Factor and Oil Temperature



8

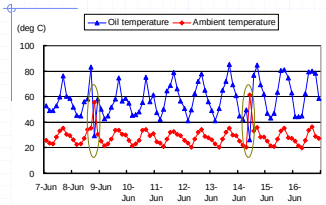
Recommendation & Information

- We should investigate the reason why this transformer stopped in detail.
- We should investigate the influence at customer in detail.
- Availability: 94.6%
  - 30days x 24hrs = 720hrs

$$\frac{720 - 39}{720} = 94.6\%$$

9

Doubtful Data



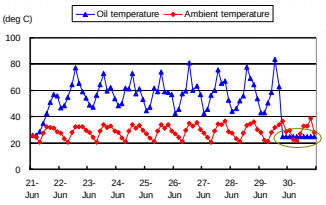
10

Recommendation

- We should check data logging procedure.
  - How to write data log sheet every day/hour by operators
  - How to check data by supervisor
  - How to make monthly report

11

Not Working Meter



12

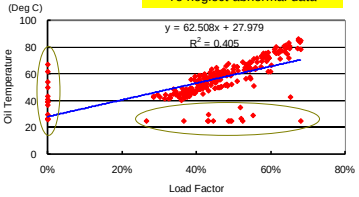
Recommendation

- We should check Oil temperature metering system immediately.
  - Meter
  - Connecting cable
  - Sensor
  - Mechanical system (at data conversion)

13

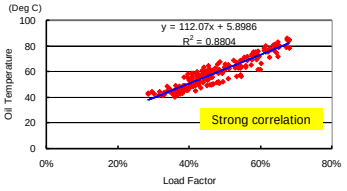
Relation between Load Factor and Oil Temperature

To neglect abnormal data



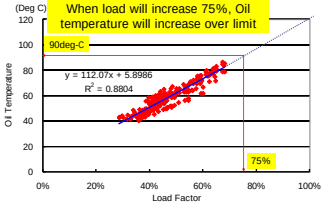
14

Relation between Load Factor and Oil Temperature



15

Relation between Load Factor and Oil Temperature



16

Recommendation

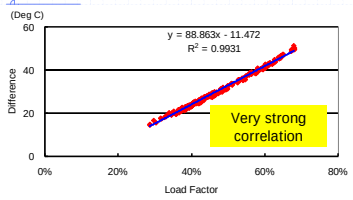
- We cannot supply electricity when load factor increase more than 75%.
- We should start to study for increasing supply capacity immediately.
  - To install cooling system (fan)
  - To install more transformer
  - To replace transformer to bigger one

17

Other Information

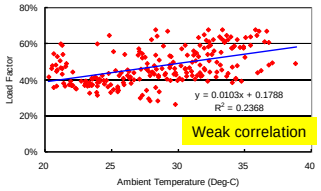
18

Relation between Load Factor and Temperature Difference



19

Relation between Ambient Temperature and Load Factor



Thank you for your kind attention

21

Exercise: How to use Excel effectively?

How to Use Excel Efficiently

(on the presentation)
(Review for more impressive Presentation)

15 July, 2014
JICA
TOKYO ELECTRIC POWER COMPANY

TOKYO ELECTRIC POWER COMPANY

Contents

1. Purpose for this Presentation.
2. Reviews of the previous presentation.
3. Explain for some Excel Function
5.Summary

1. Purpose for this Presentation.

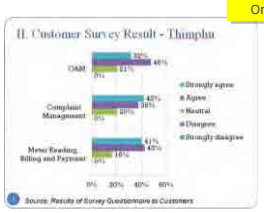
- Looking back presentation of the PI report meeting of September last year, and we think about more effective way for some figures (graph) on presentation today.
- Introduce some Excel function.

2. Reviews of the previous presentation
2.1 Case study 1

Case study 1
Theme 6b (at PI Final presentation)

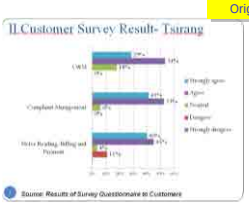
2. 1 Case study 1

Original



2. 1 Case study 1

Original



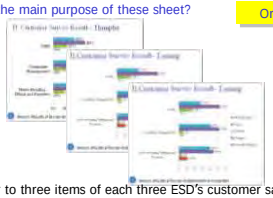
2. 1 Case study 1

Original

2. 1 Case study 1

What is the main purpose of these sheet?

Original

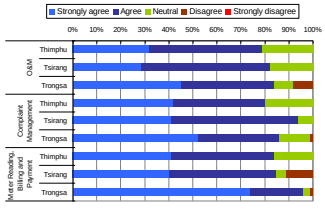


Compeer to three items of each three ESD's customer satisfaction about "O&M", "Complements Management" and "Meter reading, billing situation"

2. 1 Case study 1

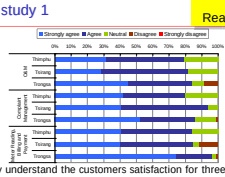
After Rearrangement

Countermeasures what we think...



2. 1 Case study 1

After Rearrangement



We can easily understand the customers satisfaction for three items, and easily to compare three ESD's situation
- ✓Almost all customer of these three ESD are satisfying tier service.
- ✓Tongsa ESD: Three item are hi compaired with other ESD.
- ✓These three items seems to related to each other.
- ✓Trongsa ESD seems has some trouble at O&M, Tsirang ESD seems has ploblam at meter Reading, Billing and paiment. Etc.

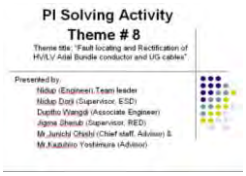
2. 1 Case study 2

Original

Good practice

2. 1 Case study 3 & 4

Case study 3 & 4
Theme 6b (PI Final presentation)



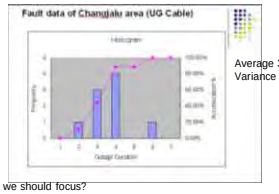
2. 1 Case study 3

Original

We can easily understand detail of the UG Cable fault.
But Presentation time is very short, so audience can't understand "causes of Outage".

2. 1 Case study 3

After Rearrangement



Average 3.450
Variance 1.3583

What point we should focus?
We think outage duration of the UG Cable is most important point.
In this case, Histogram of Outage Duration is more impressive for audiance.

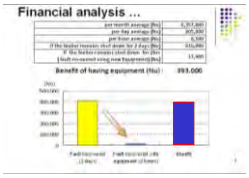
2. 1 Case study 4

Original

The size of the pie chart is related to the amount of money.
More effective to explain the amonut of money when using a bar graph.

2. 1 Case study 4

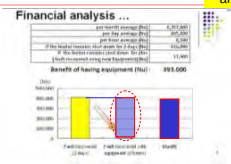
After arrangement



More effective to explain the amonut of money when using a bar graph.

2. 1 Case study 4

After arrangement



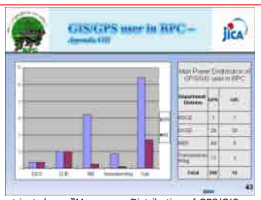
We can easily understand the benefit what introduce new equipments and use it.
✓If will use new fault detecting equipment, There is a possibility to ensure the interests of 393 thousand Nu as abenefit. Etc.

2. 1 Case study 5

Case study 5
Theme 9 (at PI Final presentation)

2. 1 Case study 5

Original



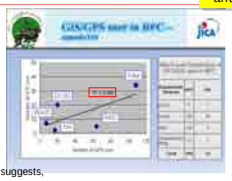
This bar chart just shows "Man power Distribution of GPS/GIS user in BPC".
But if we use scatter chart (rearrangement) ...

2. 1 Case study 4

After arrangement

2. 1 Case study 4

After arrangement



Scatter chart suggests,
✓Whether are there existing correlation between two values?
✓Validity of the asymptotic curve .
In this case
✓There are no relation GPS user and GIS user in BPC each division.

3. Explain for some Excel Function
3.1 Economic analysis(IRR, NPV)
3.1.1 NPV: Net Present Value

Case study : Purchase of UG Faulty point detector

Table 3.1 Assumptions sheet

UG Faulty point detector	5,000,000	Nu
Incidence of UG Fault (Assumption)	0.25	per month
Benefit having/using new equipment	400,000	Nu
Benefit having/using new equipment per Year	1,200,000	Nu
Interest Rate	10.0%	percentage

How much is Present value at the time of the consideration of the 7 years after of this investment?

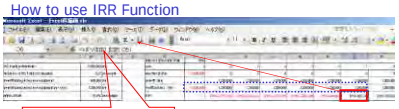
BTN 206,000 (Appx.)

Table 3.2 NPV Calculation sheet

Interest (Discount) Rate	10%									
year	1	2	3	4	5	6	7	8	9	10
Investment (Nu)	5,000,000	0	0	0	0	0	0	0	0	0
Benefit (Nu)		1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Profit and loss (Nu)	5,000,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
NPV		BTN -3,553,719	BTN 2,852,141	BTN 1,832,525	BTN 1,087,420	BTN 410,051	BTN 205,739	BTN 765,548	BTN 1,274,465	BTN 1,737,117

3.1.1 NPV: Net Present Value

How to use IRR Function



=NPV($I$1,$I$5:N5)

1st step : make a NPV Function sheets
take a quote of equipment, Calculation of benefit about every year
2nd step : calculate NPV used by the function of Excel
3rd step : Management judgment/Proposal to the higher authority

3.1.2 IRR: Internal Rate of Return

Case study : Purchase of UG Faulty point detector

Table 3.1 Assumptions sheet

UG Faulty point detector	5,000,000	Nu
Incidence of UG Fault (Assumption)	0.25	per month
Benefit having/using new equipment	400,000	Nu
Benefit having/using new equipment per Year	1,200,000	Nu

How much is the Benefit will return at the 6 years later?

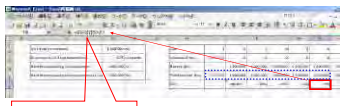
6%

Table 3.2 IRR Calculation sheet

year	1	2	3	4	5	6	7	8	9	10
Investment (Nu)	-5,000,000	0	0	0	0	0	0	0	0	0
Benefit (Nu)		1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
Profit and loss (Nu)	-5,000,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000	1,200,000
IRR		#NUM!	-38%	-15%	-2%	6%	12%	15%	17%	19%

3.3.2 IRR: Internal Rate of Return

How to use IRR Function

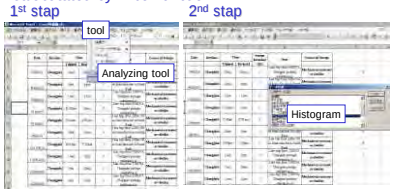


=IRR($I$5:N5)

1st step : make a IRR Function sheets
take a quote of equipment, Calculation of benefit
2nd step : calculate IRR used by the function of Excel
3rd step : Management judgment/Proposal to the higher authority

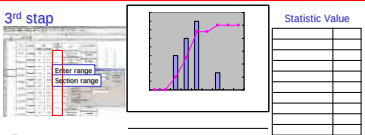
3.2 Statistic analysis
3.2.1 How to make histgram

Calucutated by Excel function
1st stap 2nd stap



3.2.1 How to make histgram

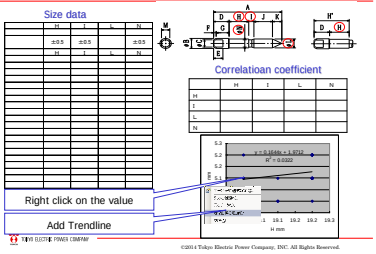
3rd stap



Easy to get
histogram and datas.

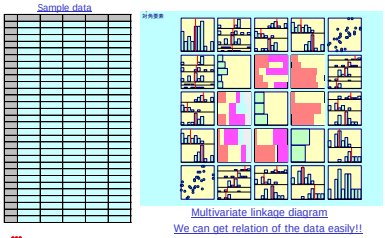
3.2.2 Correlation coefficient

Size data



Appendix.
Example of the statistical software calculation output

Sample data



Multivariate linkage diagram
We can get relation of the data easily!!

4. Summary

When you use the Excel chart in a presentation, consider what you want to express.
If effective use of the various functions of Excel, and lead to simplification of your work.
If you want to make a more complex statistical analysis, we recommend the use of statistical software.
We are expecting further development of BPC, and we will support from Japan.