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# New Framework for Japanese Electric Industry to Enhance Reactor Safety

April 19, 2012

The Federation of Electric Power  
Companies of Japan (FEPC)

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## Outline of the Accident at Fukushima Dai-ichi NPP and Counter Measures

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- ◆ Reactors shut down automatically by the earthquake and emergency power systems were actuated.
- ◆ All electric powers including emergency power were lost due to tsunami and reactor cooling function were lost.

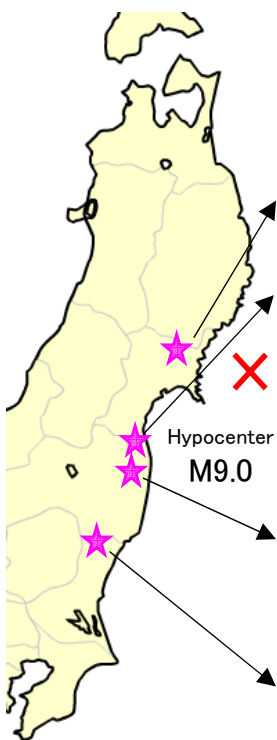
### 【Effects of earthquake】

- All reactors shut down automatically by the earthquake struck.
- All emergency diesel generators (EDG) automatically actuated.  
(Off-site power was lost due to a landslide around the off-site transmission tower.)
- Components necessary for cooling the reactors functioned properly.



### 【Effects of tsunami】

- Important facilities such as EDG, switchboards and batteries were flooded.
- Seawater pumps (SWP) were damaged and the ultimate heat sink (UHS) was lost (loss of reactor cooling functions).
- All AC power was lost (all off-site power and emergency diesel generators were lost).



	Earthquake		Tsunami				Fuel Damage	
	Power Supply (Off-Site Power/EDG)	Cooling Function	Tsunami Height (m)	NPP Altitude (m)	Power Supply			Cooling Function
		SWP			Off-site Power	EDG		
<b>○: Outage</b> Onagawa 1,2,3	○ (○/○)	○	13	13.8	○	○	○	Intact
Fukushima Dai-ichi 1,2,3,4 5,6	○ (x/○)	○	15.5 (Submerged)	10 (Unit 1 to 4) 13 (Unit 5,6)	x (Tsunami)	Unit 1 to 5 x Unit 6 ○	Unit 1 to 4 x Unit 5,6 x→○ A few days later	Unit 1 to 3 (Damaged) Unit 4 to 6 (Intact)
Fukushima Dai-ni 1,2,3,4	○ (○/○)	○	14.5 (Submerged)	12	○	Unit 1,2 x Unit 3,4 ○	Unit 1,2,4 x→○ A few days later Unit 3 ○	Intact
Tokai Dai-ni 1	○ (x→○/○) A few days later	○	5.3	8	Earthquake x→○ A few days later	○	○	Intact

- ◆ Loss of electric supply and cooling function due to tsunami continued for a long time, causing a serious situation with severe damage to the fuel and failure of containment vessels.
- ◆ Apply multiple and diversified measures to maintain electric power and water supply and to prevent flooding in order to prevent similar severe accident.

## 【Safety Measures】

Point of View

Never happen a similar severe accident again



“**Multiplexing**” and “**Diversification**”  
for “to shut off” and “to confine” function

- Assurance of power supply
- Assurance of water supply
- Measures against flooding

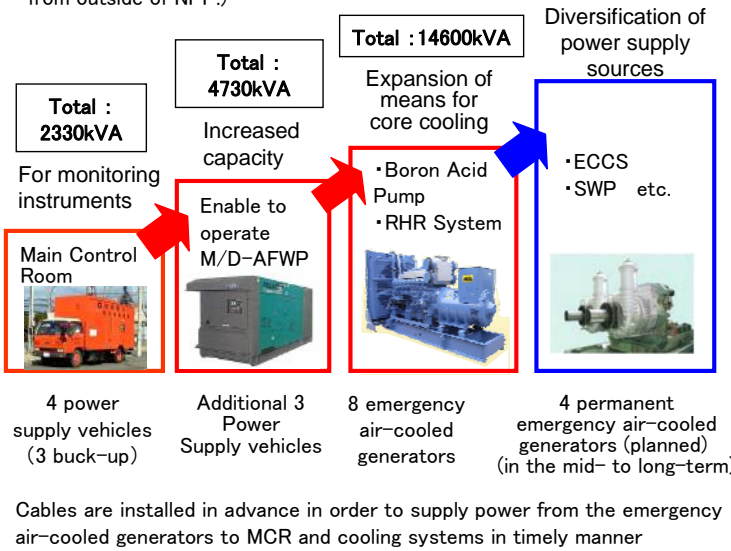
## Measures to Enhance Nuclear Safety (Emergency Safety Measures)

(Example at Ohi NPP of Kansai Electric Power)

- ◆ Power supply vehicles and emergency air-cooled generators were applied to assure electric supply. And, install of permanent emergency air-cooled generators are planned.
- ◆ Established the organization, drills and procedures for emergency preparedness

### Application of equipments and components (allocated at 30m above sea water level)

Fuel : Heavy oil (Enable 85 days continuous operation without fuel supply from outside of NPP.)



### Drills and Procedures

Measures for rapid connection of deployed power supply vehicles and emergency air-cooled generators to the appropriate points:

- Establish the Organization
- Prepare Procedures
- Perform Drills

Out-of-hours	Always 8 members are on standby
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Power supply vehicles deployment, power cables connection and power supply vehicles operation



#### ○ Feedback on drills

- Wearing headlamps for nighttime work
- Improving the shape of connection terminals for ease of work, etc.

#### ○ Reduction of time required for connection by improving facilities

Power supply vehicles: 135 minutes ⇒  
Emergency air-cooled generator: 78 minutes  
(Actual time required to complete power supply to all units during the drill)

# Status of Installation of Emergency Air-Cooled Generators (Example at Ohi NPP of Kansai Electric Power)

### Emergency air-cooled generators



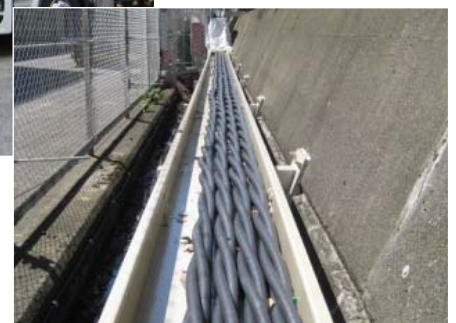
Capacity : 3,650kVA  
(1,825kVA × 2)

- Installed at a location higher than 30 m above sea level
- Rapid connection by installation of connection board and cables

### Connection board



### Installation of cables



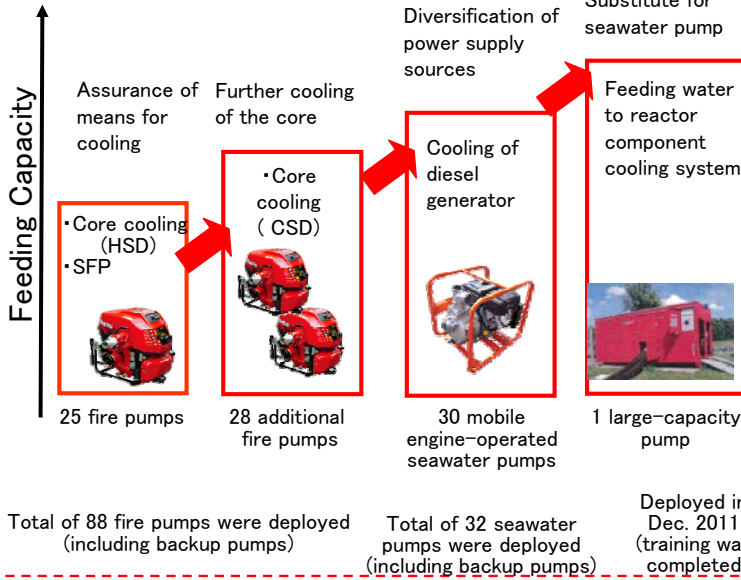


(Example at Ohi NPP of Kansai Electric Power)

- ◆ Fire pumps, mobile engine-operated seawater pumps and large capacity pump were applied to assure water supply.
- ◆ Established the organization, drills and procedures for emergency preparedness

### Application of equipments and components

Fuel : Gasoline (Enable 16 days continuous feeding without fuel supply from outside of NPP.)



### Drills and Procedures

For rapid installation of the deployed fire pumps, etc. to the appropriate points:

- Establish the Organization
- Prepare Procedures
- Perform Drills

Feed to SG
Feed to SFP
Transition to CSD

Installation of pumps, hoses  
Operation of pumps and refilling fuel



#### ○ Feedback on drills

- Points where pumps should be installed were marked.
- Radios were deployed for close communication, etc.

#### ○ Number of standby equipment and supplies

- A total of 87 fire pumps were deployed, although only 53 are required.
- A total of 670 hoses were deployed, although only 631 are required.

## Status of Installation of Large Capacity Pump (Example at Ohi NPP of Kansai Electric Power)

### Large Capacity Pump

- Installed at a location higher than 30 m above sea level
- Move to the designated point, then pump seawater



### Pump Starting-up



### Discharge Side

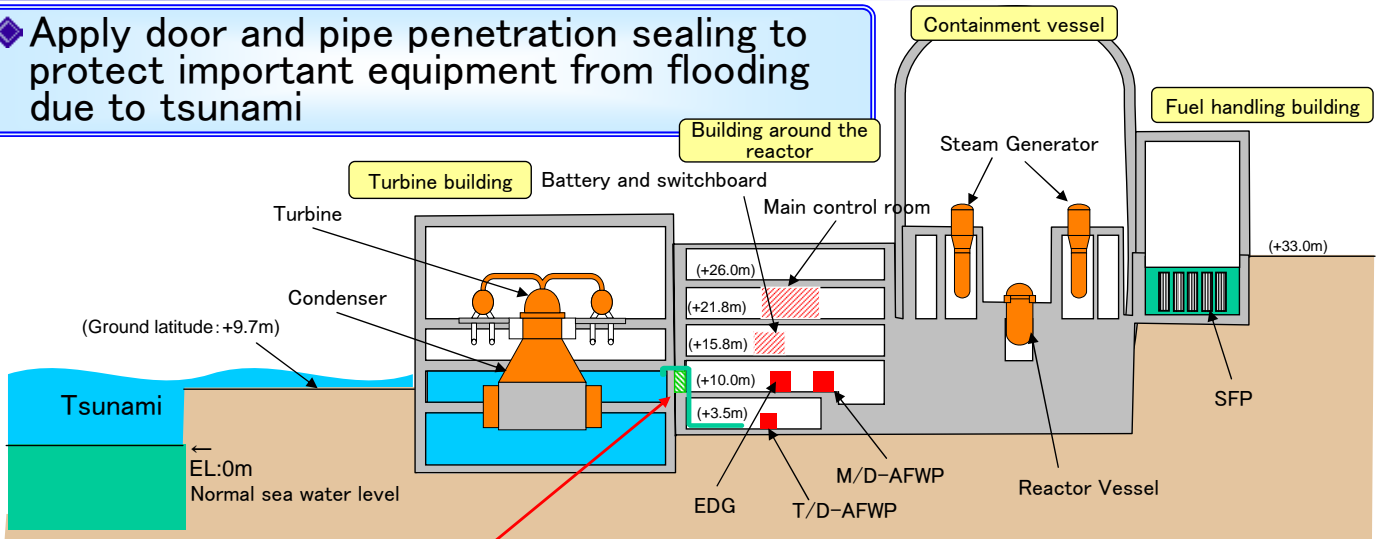


### Suction Side

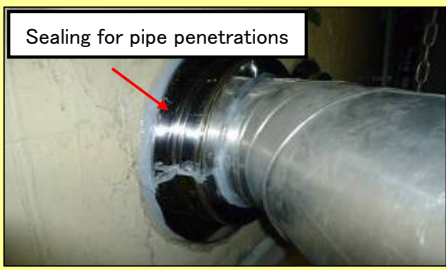


Capacity:  
1,320 m<sup>3</sup>/hr

◆ Apply door and pipe penetration sealing to protect important equipment from flooding due to tsunami



Measures to protect facilities from tsunami

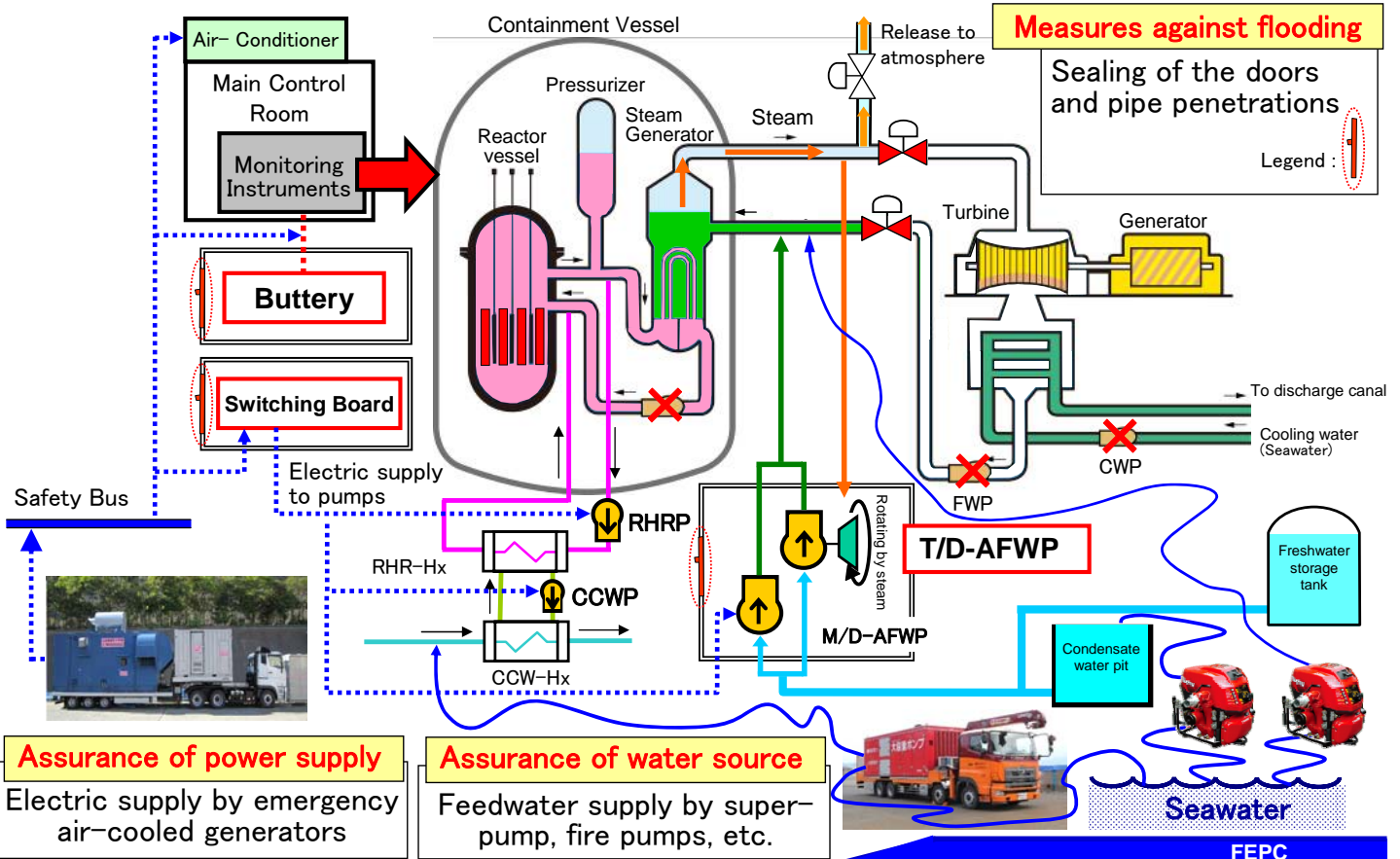


Examples of equipments applied submersion protection

- Facilities required for supplying power to the main control room (Battery room/metal clad switchgear room)
- Facilities required for supplying water to the steam generators (Pump room/metal clad switchgear room)

## Various Measures to Enhance Safety ever applied

(Example of a Pressurized Water Reactor (PWR))

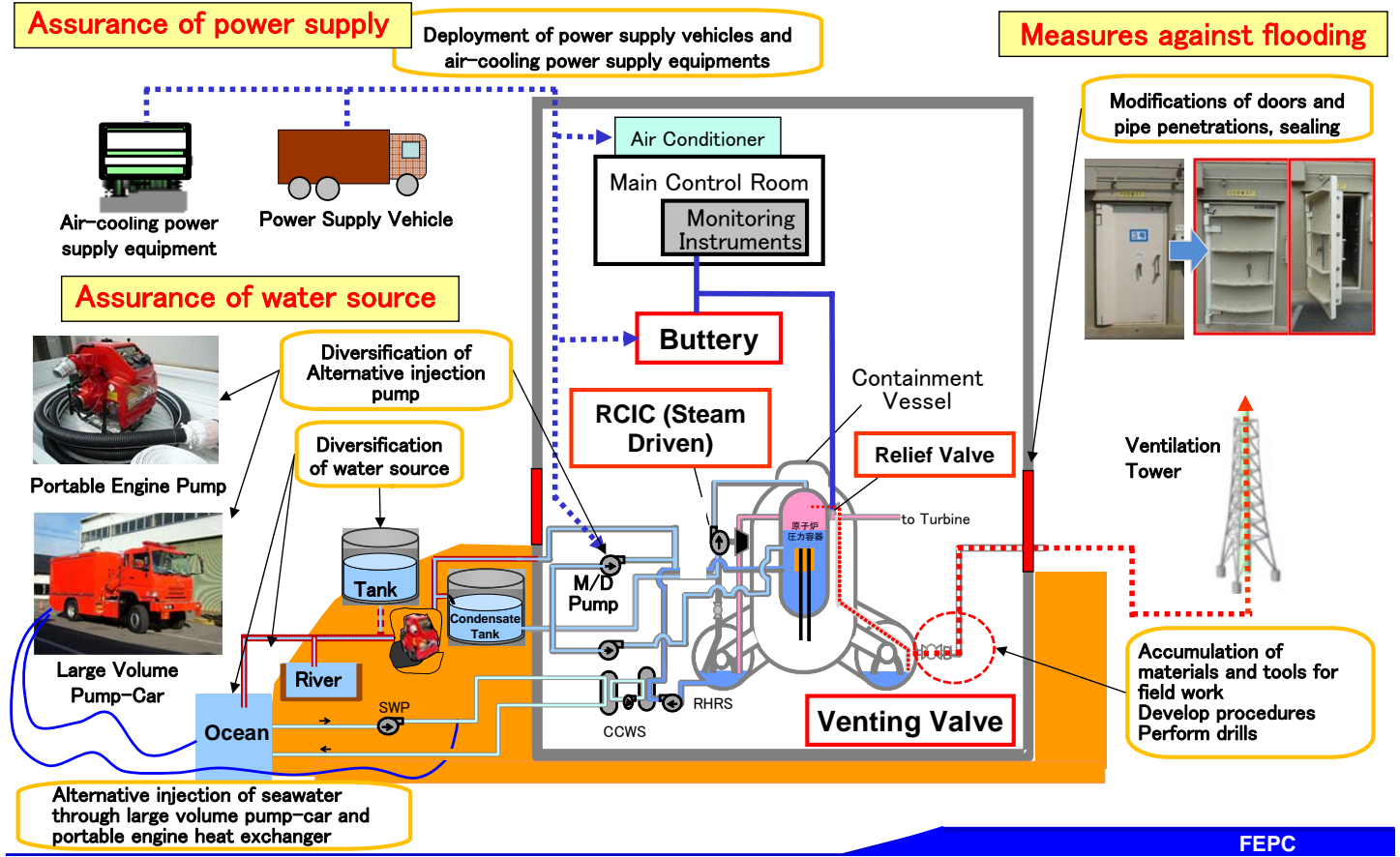


**Assurance of power supply**  
Electric supply by emergency air-cooled generators

**Assurance of water source**  
Feedwater supply by super-pump, fire pumps, etc.

# Various Measures to Enhance Safety ever applied




(Example of a Boiling Water Reactor (BWR))



# Measures to ensure effective safety

(Examples of Kansai Electric Power)

◆ To increase the effectiveness of safety efforts, various measures were applied that reflect the experience of those who were on-site during the accident.

Work environment	On-site and station-to-station communication	Radiation management	Prevention of hydrogen explosion	Removal of rubble
<ul style="list-style-type: none"> <li>Develop procedures for steady operation of the main control room ventilation system (recirculation system) during an accident.</li> <li>Secured area next to Main Control Room for commanding in case of emergency</li> </ul>	<ul style="list-style-type: none"> <li>Walkie-talkies</li> <li>Portable communications equipment</li> <li>Satellite phones</li> </ul>	<ul style="list-style-type: none"> <li>High dose protective wear</li> <li>Mutual lending of equipment and materials between electric utilities</li> </ul>	<ul style="list-style-type: none"> <li>Develop procedures for proper ventilation from annulus during an accident.</li> </ul> <p>(For Ohi NPP Unit 1 and 2, power supply to an igniter has been confirmed.)</p>	<p><b>Wheel Loader</b></p> 
<p>Strengthening emergency preparedness</p>				
	<ul style="list-style-type: none"> <li>Strengthened emergency preparedness and support systems. (examples in Ohi NPP)</li> <li><b>Support system consists of 800 persons</b> (Reinforced resident staff in NPP) : 29 → 54 persons</li> <li>(Reinforcement of support system) - Readiness for emergency : Call up 160 persons</li> <li>- Reinforced vendor's support : 500 persons</li> <li>Establish regional support centre (including HQ)</li> <li>- Reinforce contractor's support : 150 persons</li> <li>Improved communication systems, and more.</li> </ul>		<p><b>Bulldozer</b></p> 	<p><b>Crawler Carrier</b></p> 

## Improvement of the Safety evaluated by Stress Test (Primary Assessment)

## Stress Test (Primary Assessment)

- ◆ Conducted a stress test (primary assessment) to quantify the effectiveness of safety measures.

### 【 Points evaluated 】

- The safety margin and vulnerability of the entire plant during an event beyond expectations.
- Assurance of multiple means to deal with an event beyond expectations.
- The degree to which emergency safety measures have enhanced safety.

### 【 Main items evaluated 】

- Earthquake: The degree to which an earthquake beyond expectations can be endured without fuel damage
- Tsunami: The degree to which a tsunami beyond expectations can be endured without fuel damage
- Station Black Out and Loss of Ultimate Heat Sink:  
The degree to which the power station can endure a total black out (total loss of AC power) and loss of the ability to take in ocean to remove the heat from fuel (loss of ultimate heat sink) without fuel damage in the absence external help
- Severe Accident Management:  
The effectiveness of severe accident management measures developed from the viewpoint of defence in depth



◆ Confirmed improvement of the safety accomplished by emergency safety measures consist of multiplexing/diversification of power and water feeding measures.

## Outline of the accident

All reactors shutdown automatically in the wake of the earthquake (1.26 times Ss). While a collapsed off-site transmission tower and other causes led to loss of external power supply, the emergency diesel generator actuated properly and the equipment necessary for cooling the reactors functioned.



A tsunami 2.6 times as high (15.5 m) as had been anticipated in design hit the station following the earthquake caused the emergency diesel generator, sea water pumps, switching board and other structures and equipment been submerged.



Resulted station black out and loss of ultimate heat sink. Insufficient preparation for the situation made the accident worse, eventually leading to fuel damage.



## Evaluated safety of Ohi Unit 3 and 4 of Kansai Electric Power

By introduced emergency safety measures,

Ensured the safety of the station **even if 1.8 times standard earthquake Ss occurs.**

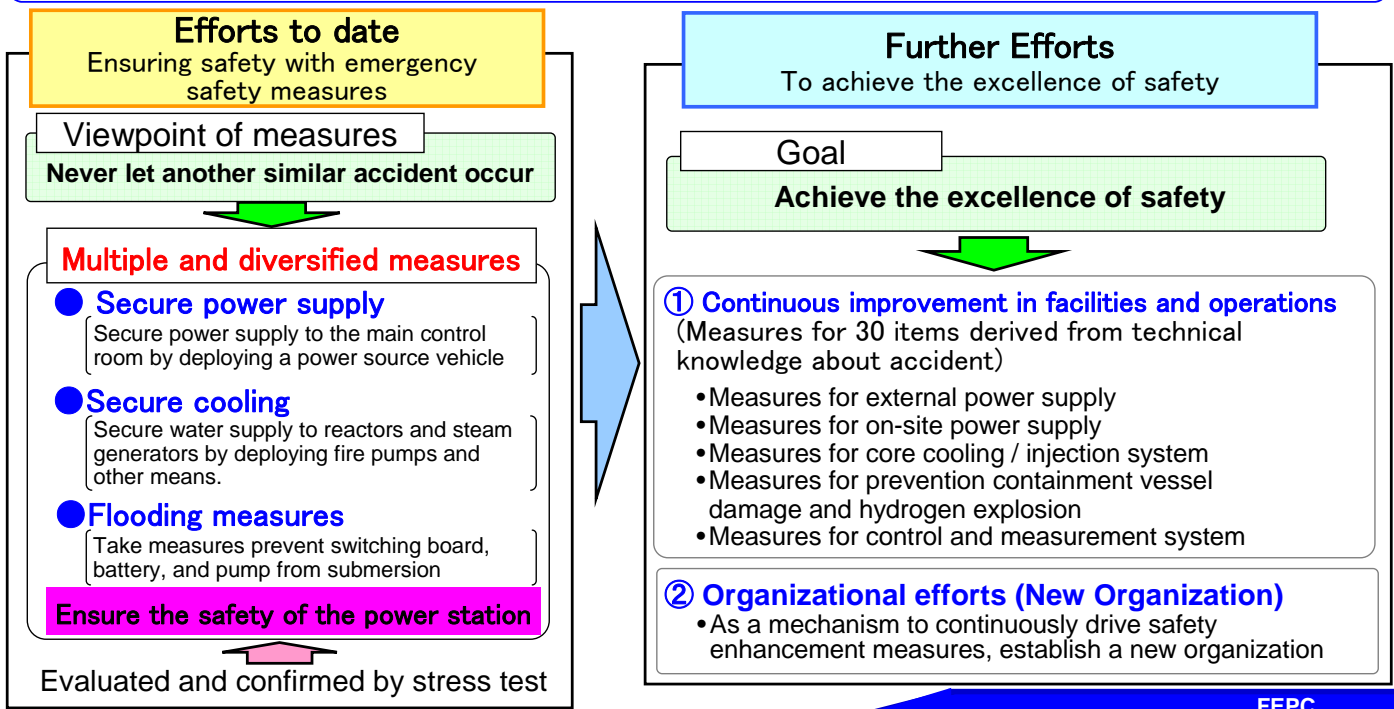
Ensured the safety of the station **even if 4 times (11.4m) higher than design anticipated tsunami (2.85m) hits the station.**

**Enable to maintain cooling of reactor for 16 days and SFP for 10 days even if station black out or loss of ultimate heat sink occurs.**

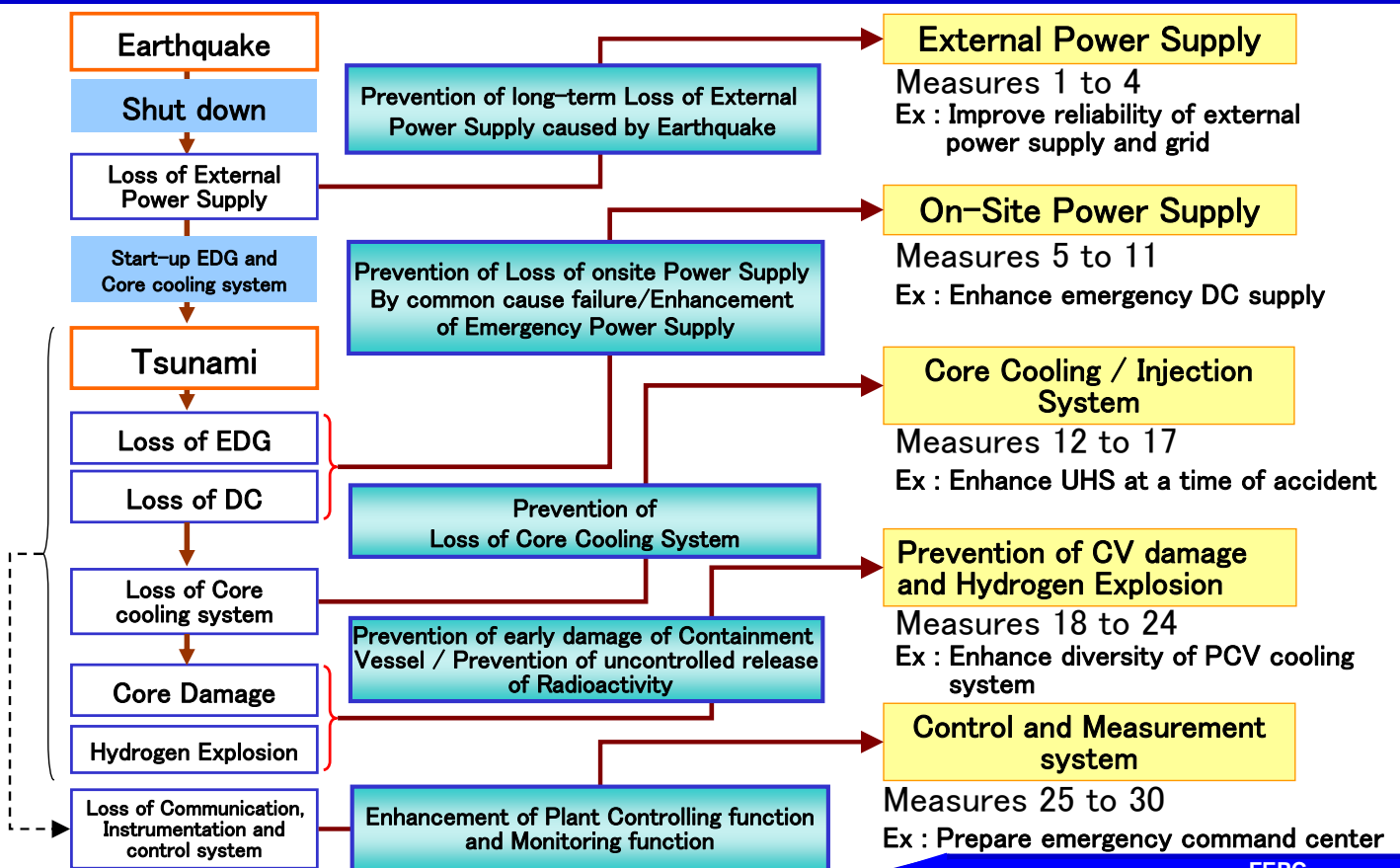
## Efforts to Further Enhance Safety

# Efforts to Further Enhance Safety

◆ In addition to the emergency safety measures ever applied, we will make continuous improvements in terms of facilities and operations, and organizational efforts in order to achieve the excellence of safety.



## 30 countermeasures derived from technical knowledge about accident at Fukushima Dai-ichi NPP (Interim report issued by NISA)



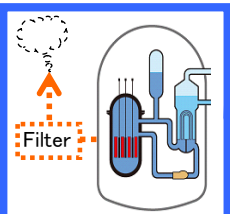
**Dedicate continuous facility and operational improvement to achieve higher safety based on the technical knowledge about the accident**


Technical Knowledge	Short term actions ; Complied	Mid/long term actions
External power supply	対策1: 外部電源系統の信頼性向上	1ルート喪失しても外部電源を喪失しないことを確認
	対策2: 変電所設備の耐震性向上	ガス絶縁開閉装置により耐震性を強化した回線を2回線確保
	対策3: 開閉所設備の耐震性向上	開閉所電気設備の安全強度を確認
On-site power supply	対策4: 外部電源設備の迅速な復旧	損傷箇所を迅速に特定できる設備が導入されていることを確認
	対策5: 所内電源設備の位置的な分散	空冷式非常用発電装置を津波の影響を受けない高所に配備
	対策6: 浸水対策の強化	重要な機器が機能喪失しないよう建物の浸水防止対策を実施
	対策7: 非常用交流電源の多重性と多様性の強化	空冷式非常用発電装置の設置、ディーゼル発電機用海水供給用可搬式エンジン駆動ポンプの設置などにより多様化・多極化
	対策8: 非常用直流電源の強化	空冷式非常用発電装置の設置により蓄電池への充電が可能(5時間以内)
	対策9: 個別専用電源の設置	重要なパラメータを監視する予備の可搬型計測機器等を手配
	対策10: 外部からの給電の容易化	空冷式非常用発電装置の配備、マニュアル整備、訓練を実施
Core cooling / Injection system	対策11: 電源設備関係予備品の備蓄	海水ポンプモーターなどの予備品を保管
	対策12: 事故時の判断力の向上	事故時操作所則にて判断基準が明確化されている
	対策13: 冷却系設備の耐浸水性・位置的分散	重要な機器が機能喪失しないよう建物の浸水防止対策を実施、消防ポンプなどの資機材を津波の影響を受けない場所に保管
	対策14: 事故後の最終ヒートシンクの強化	主蒸気逃がし弁から大気へ原子炉の前熱熱を放出する手段等の多様性を確保
	対策15: 隔離弁・SRVの動作確実性の向上	主蒸気逃がし弁の手動操作性、アクセス性を確認
Prevention CV damage and Hydrogen explosion	対策16: 代替注水機能の強化	代替注水設備の駆動源の多様化として、エンジン駆動の消防ポンプを配備、水源の多量化・多極化
	対策17: 使用済燃料プールの冷却・給水機能の信頼性向上	海水を含む複数の水源から複数の給水手段を確保
	対策18: 格納容器の除熱機能の多様化	大容量ポンプ・空冷式非常用発電装置により原子炉補機冷却機能を確保、ディーゼルの活用による格納容器クレーを用いた減圧機能を確保
	対策19: 格納容器トップヘッドフランジの過温破損防止対策	-
	対策20: 低圧代替注水への確実な移行	主蒸気逃がし弁による減圧手段の確立
	対策21: ベントの確実性・操作性の向上	PWRでは炉心冷却を蒸気発生器からの冷却で行うための、主蒸気逃がし弁の手動操作は可能
Control and measurement system	対策22: ベントによる外部環境への影響の低減	格納容器スプレッドによる放射線除去
	対策23: ベント配管の独立性確保	格納容器排気筒はユニット毎に独立
	対策24: 水素爆発の防止(濃度管理及び適切な放出)	水素がアンユラス内に流れ出ること想定し、アンユラス排気筒の運転手順を整備
	対策25: 事故時の指揮所の確保・整備	中央制御室での指揮所機能の確保
	対策26: 事故時の通信機能確保	電源等の電源から給電された通信設備(トランシーバー、衛星携帯電話など)を確保するとともに分散配備
	対策27: 事故時における計装設備の信頼性確保	重要なパラメータを監視する予備の可搬型計測機器等を手配
	対策28: プラント状態の監視機能の強化	非常用電源から電源供給される使用済燃料ピット監視カメラの設置
	対策29: 事故時モニタリング機能の強化	モニタリング用システムの電源対策として、非常用電源からの供給、バッテリー容量の増加、専用のエンジン発電機設置
	対策30: 非常事態への対応体制の構築・訓練の実施	消防ポンプなどの必要な予備品の確保、マニュアルの整備、要員の発電所常駐体制、召集方法の強化、訓練の継続実施
		変電所において耐震性を高めるため、高強度がいしへ取替
		基準地震動S <sub>1</sub> による評価を行い、必要に応じ耐震性向上対策を実施
		復旧手順を定めたマニュアルを整備、必要な資機材を確保
		既存受電設備が使用できない場合も想定し、緊急用高所受電設備を設置
		水密層への取替の実施、防波堤のかさ上げ、防潮堤の設置
		大容量の恒設非常用発電機を津波の影響を受けない高所に設置
		蓄電池を追加設置
		重要なパラメータを監視する予備の可搬型計測器等を配備
		緊急用高所受電設備の設置
		緊急用高所受電設備の設置
		現場操作機器などのマニュアルへの情報追加、教育の実施、線量予測測定の作成・シビアアクシデント対応マニュアルへの反映
		水密層への取替の実施、防波堤のかさ上げ、防潮堤の設置
		水源となるタンク周りに防護壁を設置、防波堤のかさ上げ、防潮堤の設置
		弁作動用空気確保のためのコンプレッサー等の確保
		さらに吐出圧力の高い中圧ポンプの配備、配管の恒設化
		使用済燃料ピット広域水位計の設置
		フィルタ付ベント設備の設置
		-
		SG注水機能のさらなる改善に合わせたマニュアルの充実
		フィルタ付ベント設備の設置の際にベント弁の操作性を考慮
		フィルタ付ベント設備の設置
		フィルタ付ベント設備はユニット毎に排気筒を設置
		静的触媒式水素再結合装置の設置
		事故時の指揮機能を強化するため、免震車庫様の設置
		衛星携帯電話の外部アンテナの設置、免震車庫様への通信手段移設
		重要なパラメータを監視する予備の可搬型計測器等を配備
		使用済燃料ピット広域水位計の設置、格納容器内監視カメラの活用検討
		モニタリングデータの伝送ラインの2重化、可搬型モニタリングポストの追加配備
		協力会社による支援要員派遣体制の構築、プラントメカ技術者の若狭地区への常駐、さらに必要な資機材や予備品の検討・確保

To Enhance Safety

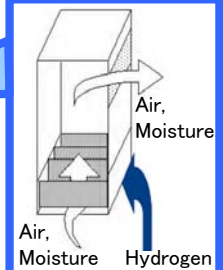
**As continuous facility and operational improvement, filtered-venting system installation, construction of a seismic isolated office building and breakwater raising are planned in the medium- and long-term period.**

**Filtered venting system**  
To minimize long term evacuation area (in 2015)

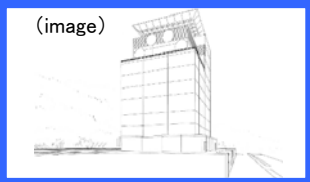




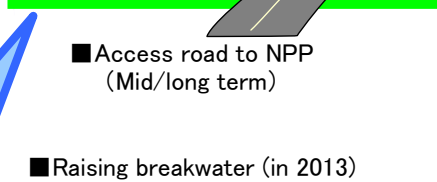
**Hydrogen explosion prevention**  
Passive Autocatalytic Recombiner (in 2013)




**Seismic isolated office building** (in 2015)  
(image)



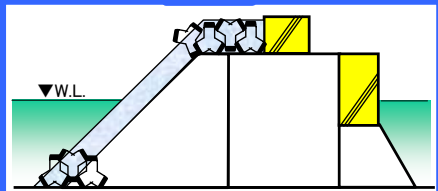
**Access road to NPP**  
(Mid/long term)



**Reinforce power line**  
(Mid/long term)



**Raising breakwater** (in 2013)



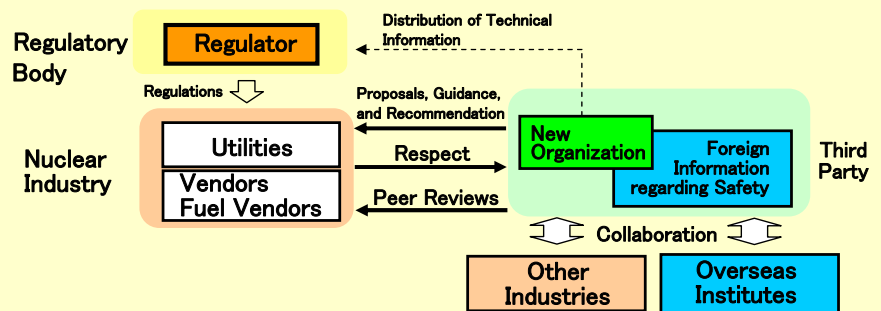
**Height of breakwater**

- Water Outlet Pit: T.P. + 15m
- Breakwater: T.P. + 8m
- Water Inlet: T.P. + 6m

◆ As a mechanism to continuously improve safety measures, we will establish a new organization by the end of 2012 to reflect the best practice and the latest findings, domestic and overseas.

**Outline of the new organization**

- ◆ Promote leading-edge safety measures, while considering measures in other countries
  - Close cooperation with overseas institutions (INPO, WANO etc.)
  - Collect and analyze information from foreign countries and deploy the latest findings to enhance the safety of each power station.
- ◆ Structure based on the commitment of top management at each electric utility
  - With independent power and authority, provide proposals, guidance, and recommendation to electric utilities in order to control over ourselves.
- ◆ Secure human resources with high technical capability
  - Combine the technical capability among the industry.



**Mission statement for the new organization**

◆ Lessons learned with regards to safety enhancement activities

In spite of the efforts to enhance nuclear safety including management of natural disaster, have we electric utilities been insufficient in;

- ❑ Management for natural disasters beyond design basis such as massive tsunami, massive earthquake, whose occurrence is extremely low?
- ❑ Examination, analysis and introduction of safety measures made in the other countries?
- ❑ Continuous pursuit of "Excellence" as whole nuclear industry in addition to putting focus highly on compliance under stable operational experiences and experience of scandals?
- ❑ Utilization of the Japan Nuclear Technology Institute (JANTI), which was established to support the safety enhancement activities of electric utilities?

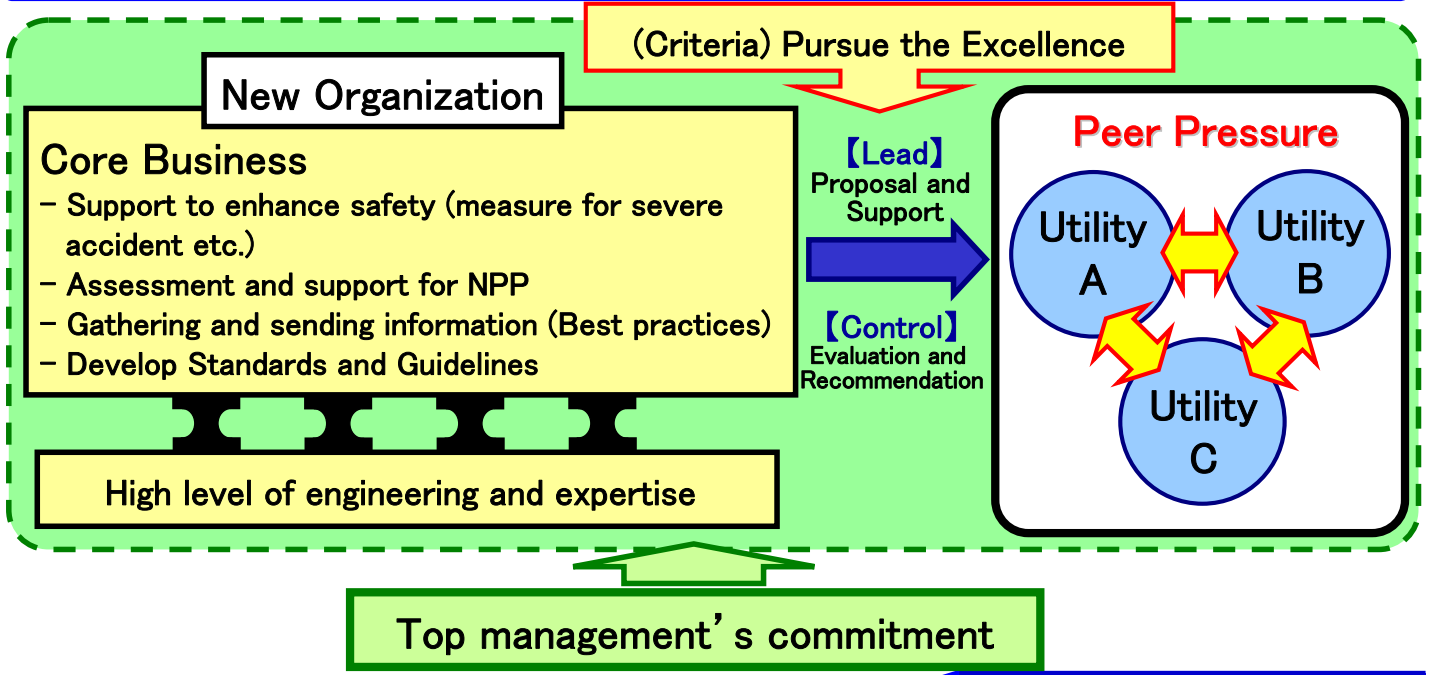
Need to create a structure promotes utilities pursuing voluntarily the world's highest level of safety.

**Mission**

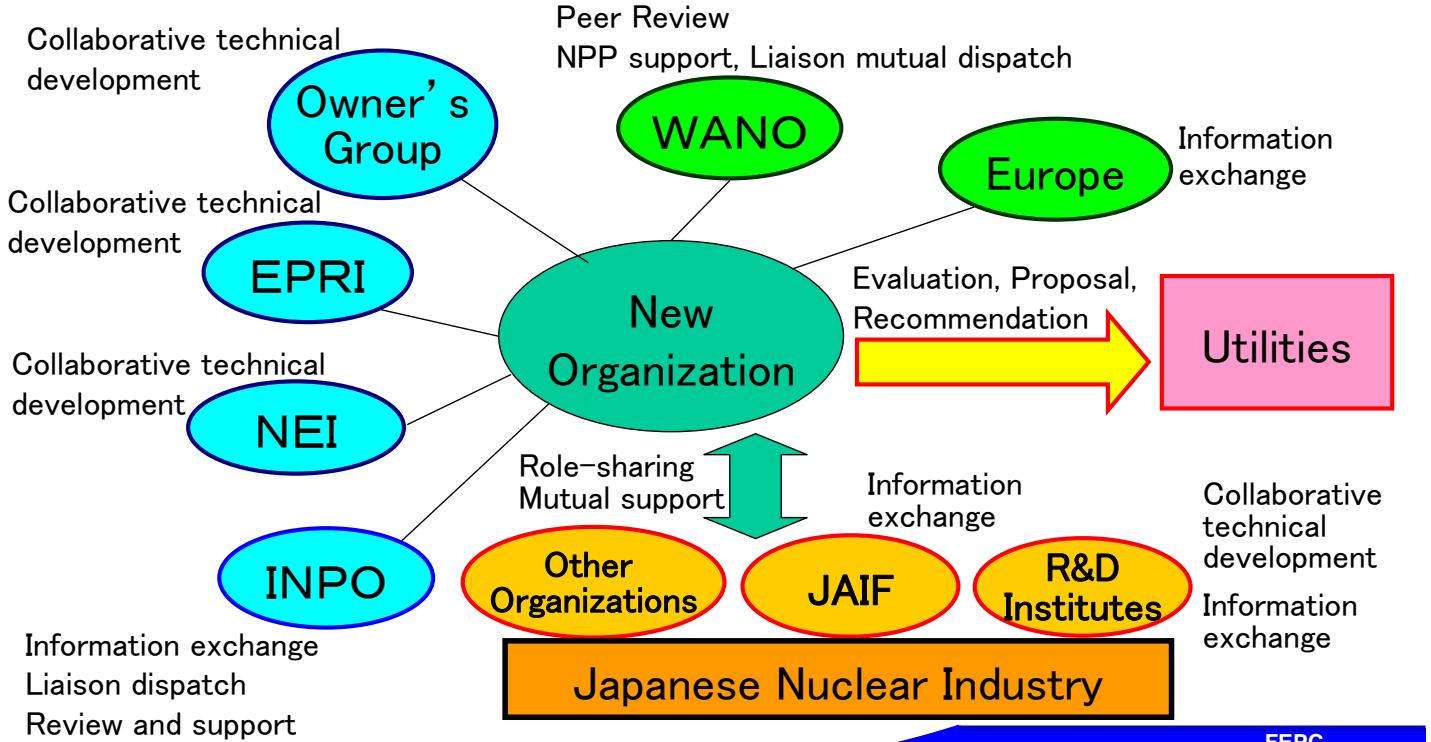
Achieve the world's highest level of safety in Japan's nuclear industry -- Pursue the "Excellence" continuously --



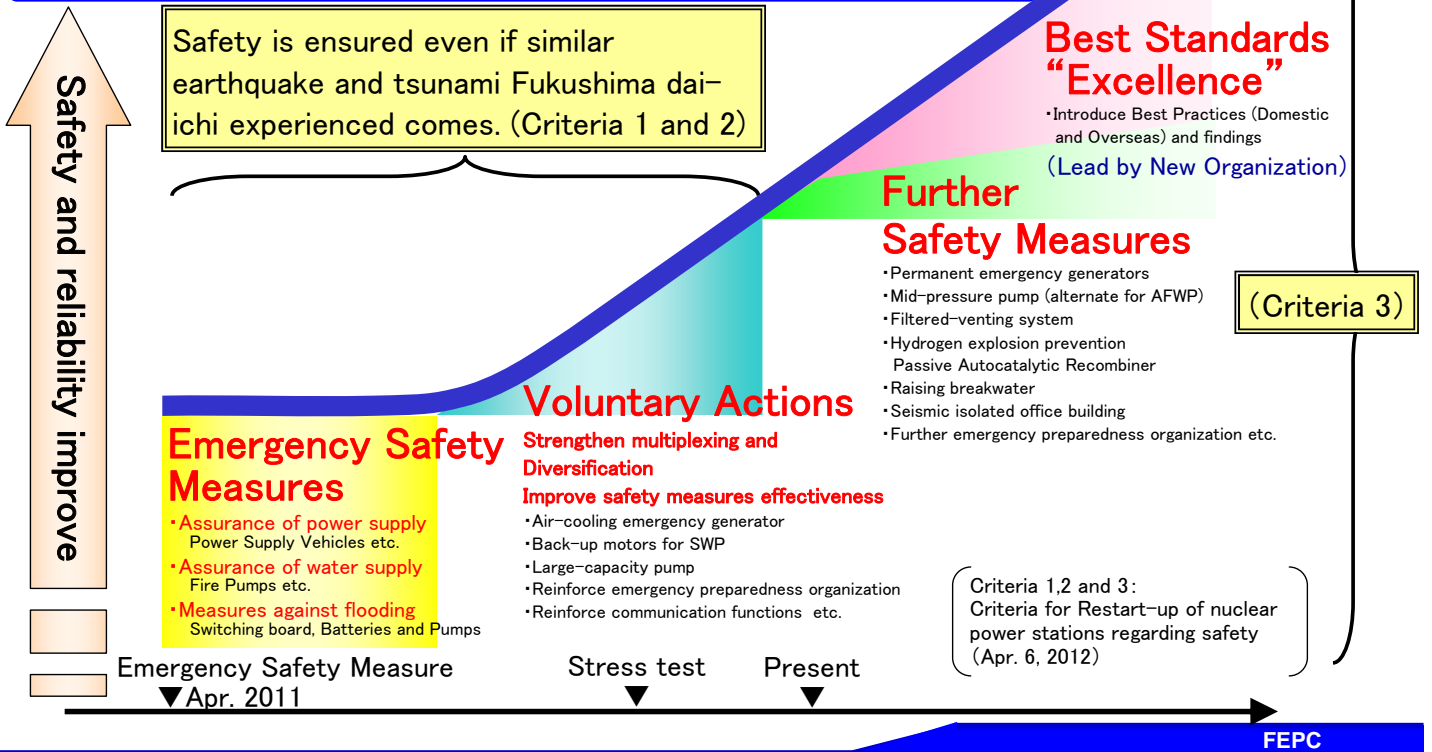
- ◆ New organization “leads” and “controls” utilities to achieve “Excellence” through their business; such as counter measures for severe accident.
- ◆ Utilities’ top management implement firm commitment in order to enhance effectiveness of new organization.



- ◆ New organization gathers information in an integrated fashion and collaborate through and with other domestic and overseas organization



◆ Continuous and voluntary dedication to enhance safety with new organization, pursuing the best standards “Excellence”



## Efforts to Restore Trust in Nuclear Energy

◆ We have been engaged in an earnest effort to clearly explain to residents in the power station's vicinity what we are doing to enhance safety and listen carefully to their opinions and concerns in the belief that this is the first step to restoring trust in nuclear energy.  
 We have also been actively engaged in public relations activities to highlight the efforts made by electric utilities to the public.  
 We will continue these efforts so that we can rebuilt public trust.

◆ Directly approach residents in the power station's vicinity to obtain their understanding

○ Activities in Fukui Prefecture

Conducted extensively; activity targets included opinion leaders, various organizations upon request, and the public in each ward.

○ Visiting residents from door to door (Mihama Town)

◆ Main public relations activities

- Published inserted informational magazines in newspapers (a total of 14)
- Ran commercials on TV
- Aired a program on cable TV
- Aired a program on a local TV station
- Posted full-page ads in newspapers
- Published a public relations magazine



[Advertisement in newspapers]



[Inserted informational magazines and public relations magazines]



[Visiting residents from door to door]

## Summary

- ◆ Ensure station safety by implementing various safety measures based on strong determination “Never have similar accident”
  - Strengthened multiplexing and diversifications of safety measures
- ◆ Pursue the best standards “Excellence” of safety
  - Drive voluntary and proactive actions by utilities
  - Never ending, continuous effort to enhance safety, advanced from regulations
  - Establish new organization and lead utilities
  - Reinforce emergency preparedness on the presumption having a severe accident
- ◆ Restore Trust in Nuclear Energy
  - Establish transparency and keep on explaining faithfully
- ◆ The nuclear industry across the world is in the same boat
  - To feed back the knowledge to global nuclear industry is Japanese utility’s mission experienced the accident at Fukushima Dai-ichi NPP.