WOOJIN

Energy Storage System

System, Application & Business Procedure

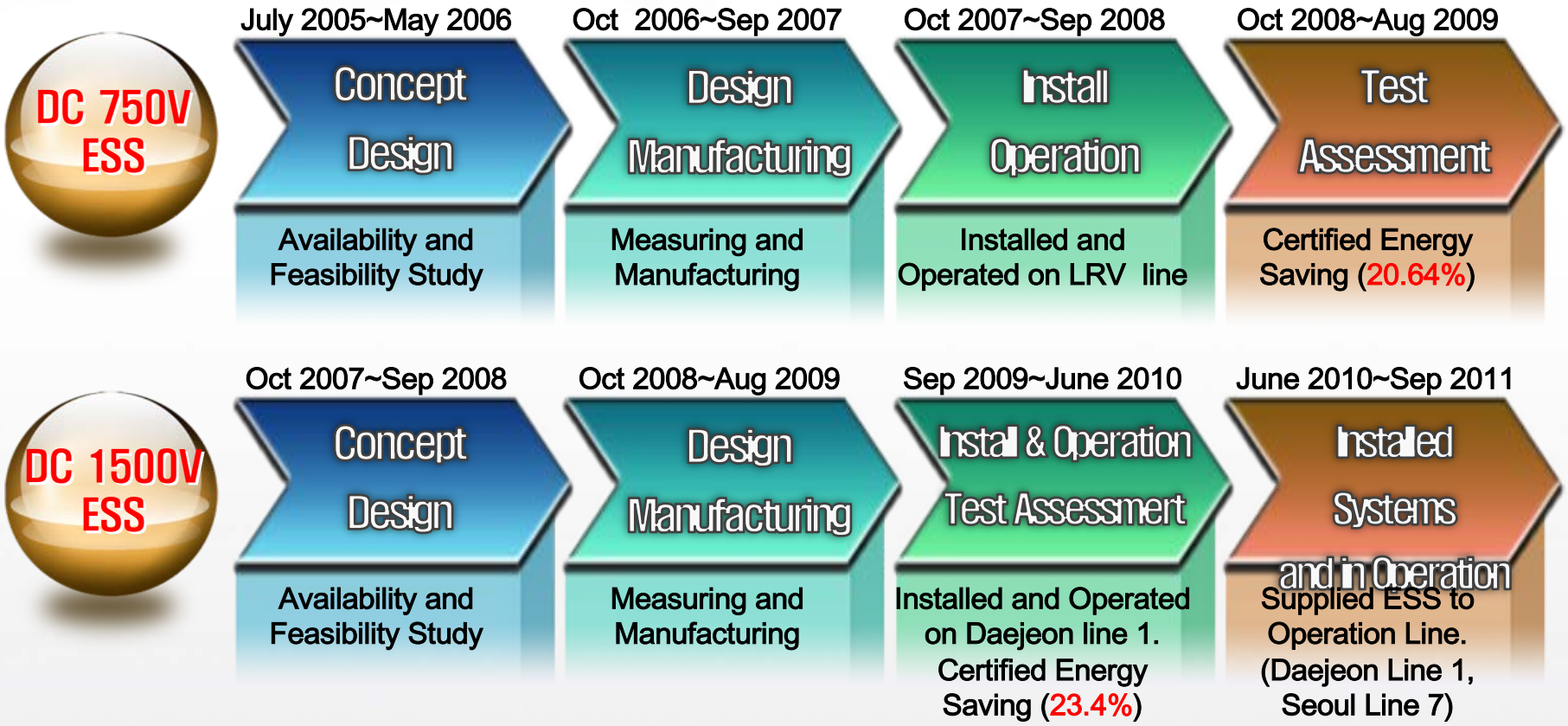
Index

I. Development History of WOOJIN Energy Storage System

I. Development History of WOOJIN Energy Storage System

Task	Energy Storage System Technology Development
Period	2005. 7. 8 ~ 2011. 10. 09
Research Cost	Governmental Funding (2 Million USD), Company Share (0.966 Million USD)

● Development Schedule



II. Mechanism of Energy Storage System

1. Regeneration Energy Occurrence and Utilization
2. Summary of Energy Storage system
3. Energy storage system characteristics

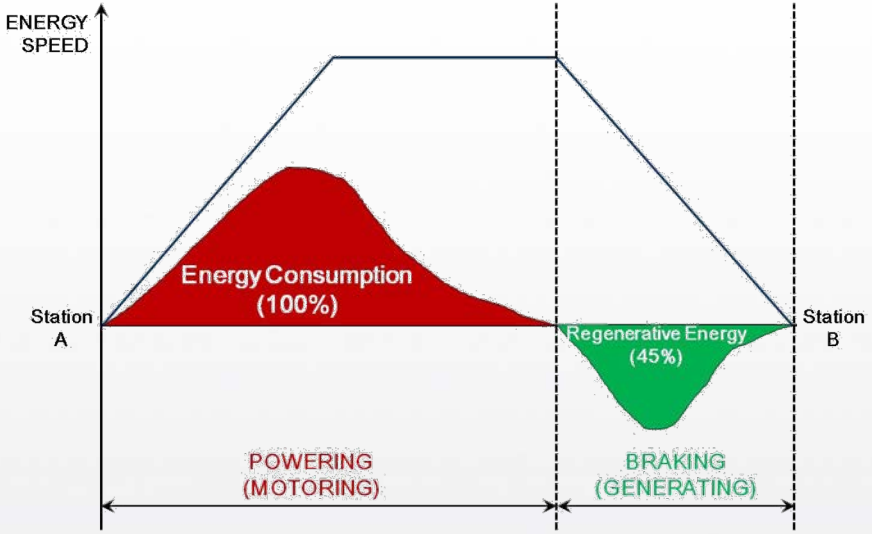
1. Regeneration Energy Occurrence and Utilization

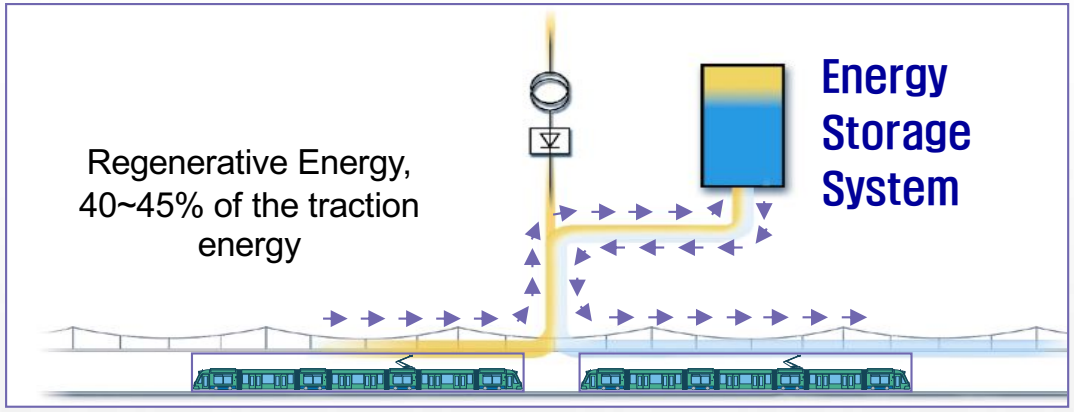
*All rolling stock systems with Regenerative Braking by **VVVF-Inverter** are capable of implying **Energy Storage System***

- Regenerative Energy occurring in single EMU corresponds to Maximum 40%~45% of Energy Consumption

- Regenerative Energy is being utilized, when powering at the same substation block
- However, when there is no other train to take regenerative energy with the same block, catenary voltage will increase
- When catenary voltage exceeds the setting voltage, Regenerative Braking is forced to stop by the control unit, activating mechanical braking system
- When more mechanical moving parts are forced to be used, the casing is worn out

- By the voltage fluctuation from the regenerative energy generated, the maintenance cost for electrical on-board equipment will be increased while the life span is shortened.





Energy Storage System

2. Summary of Energy Storage System

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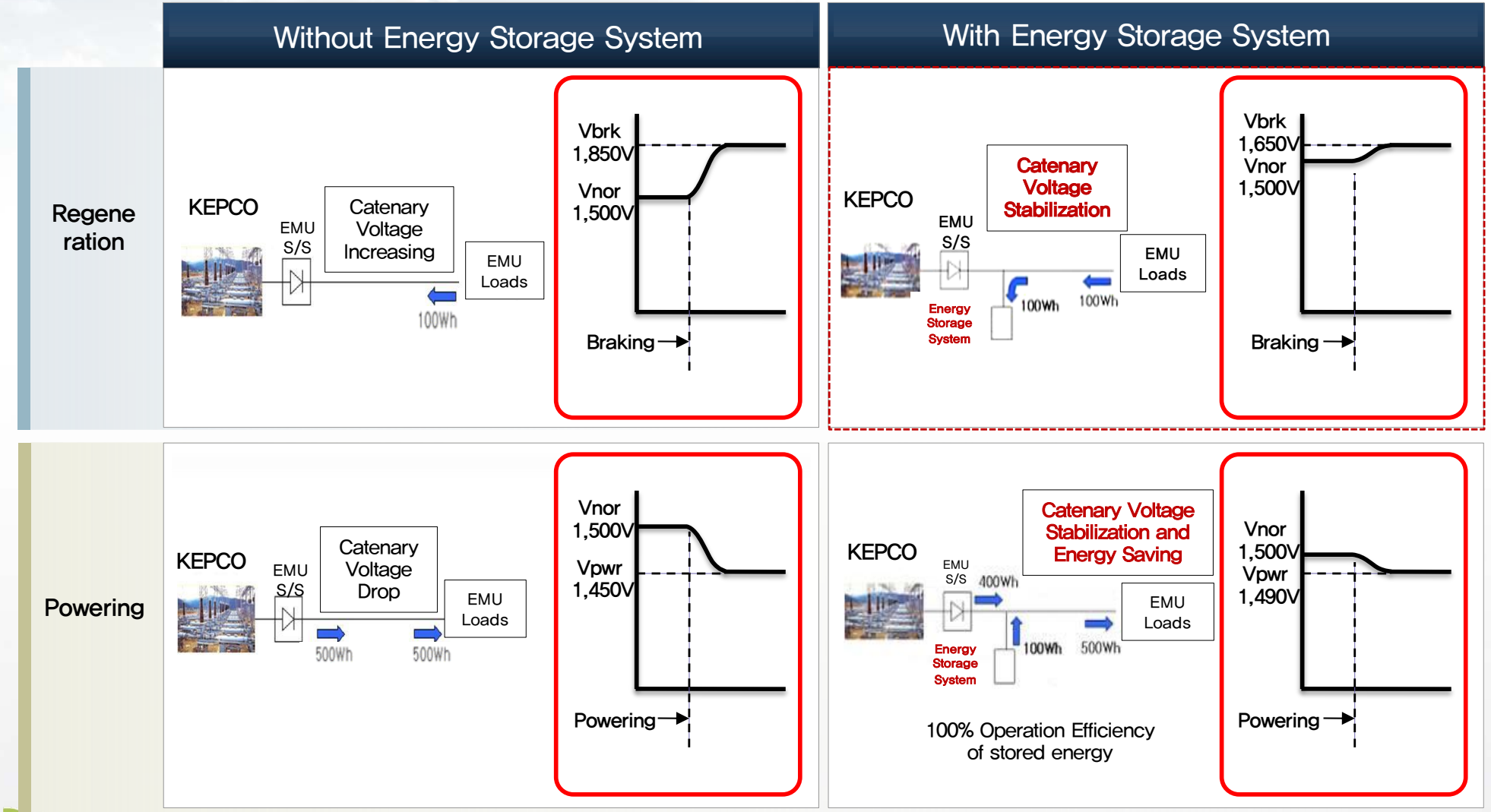
Electricity cost reduction is resulted from

the energy saving through Energy Storage System



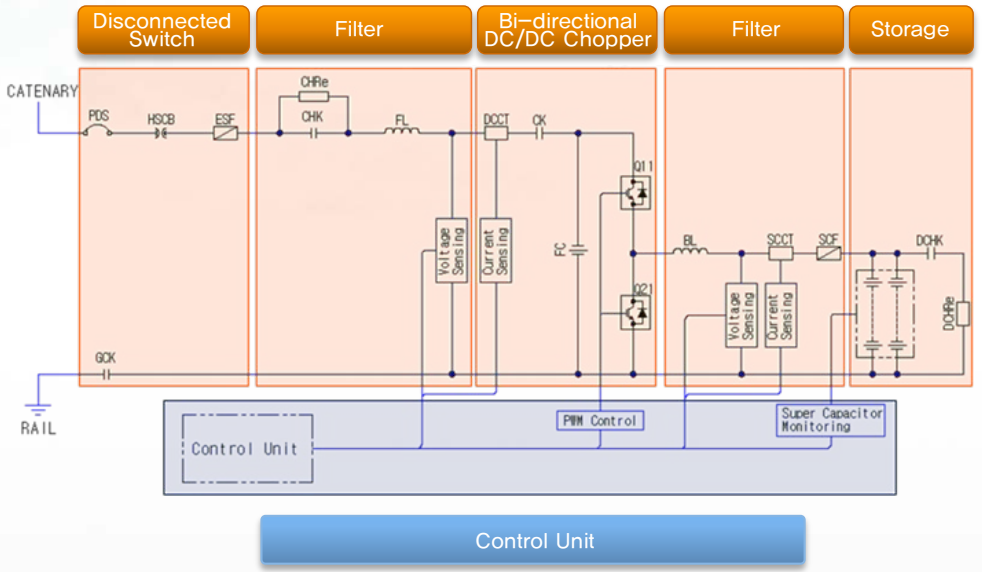
Energy Storage System

(*) KEPCO: Korea Electric Power Corp.

3. Characteristic of Energy Storage System

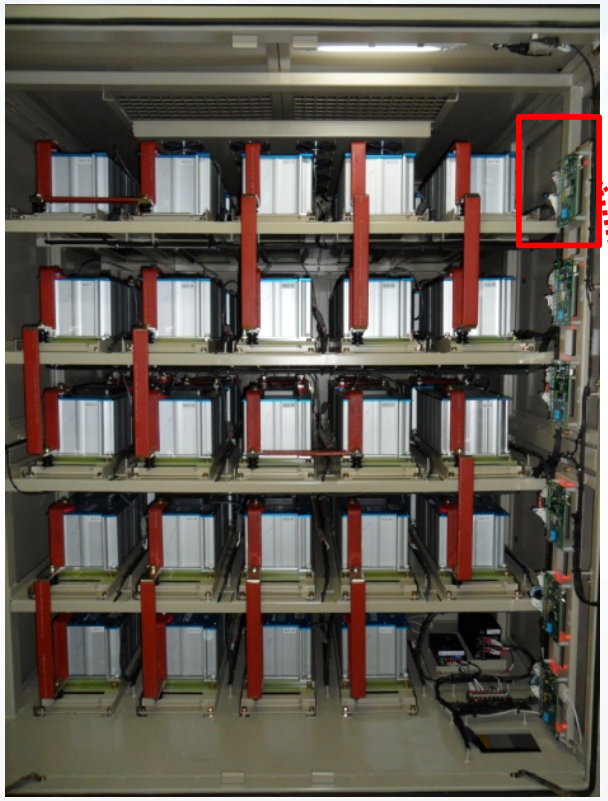
***The Energy Storage System** stores the regenerative energy of vehicle, and to be provided during the powering of other train.*

Energy Storage System Block Diagram



3. Characteristic of Energy Storage System

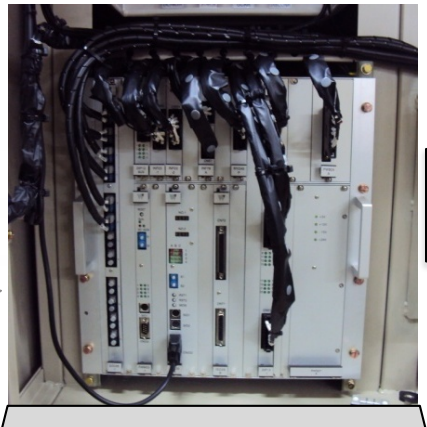
*The Energy Storage System is controlled by the **Main Controller which communicates with each Super Capacitor Module in real time***



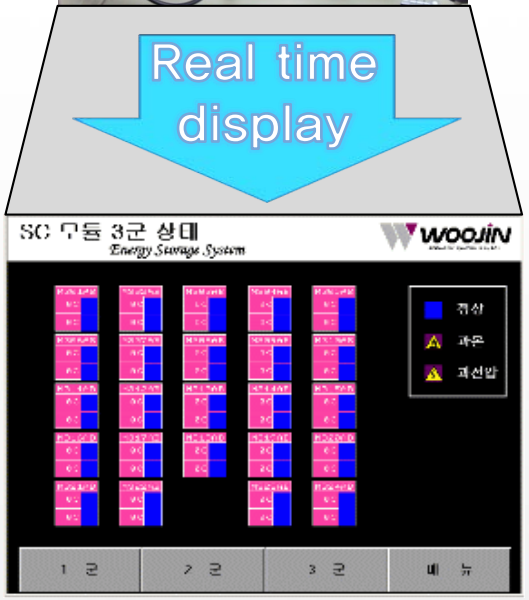
Super Capacitor unit

Real time communication

Communication Board



Main Controller



Man Machine Interface

3. Characteristic of Energy Storage System

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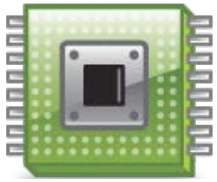
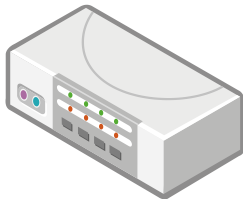
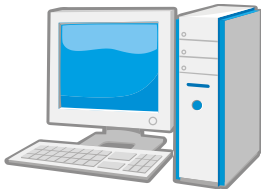
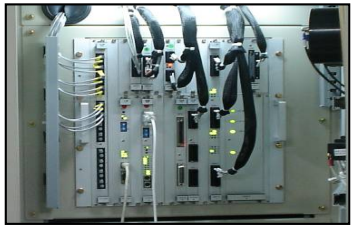
The Energy Storage System is the unmanned system controlled by the
Operation Control Center in real time communication

Substation and Remote Control Center

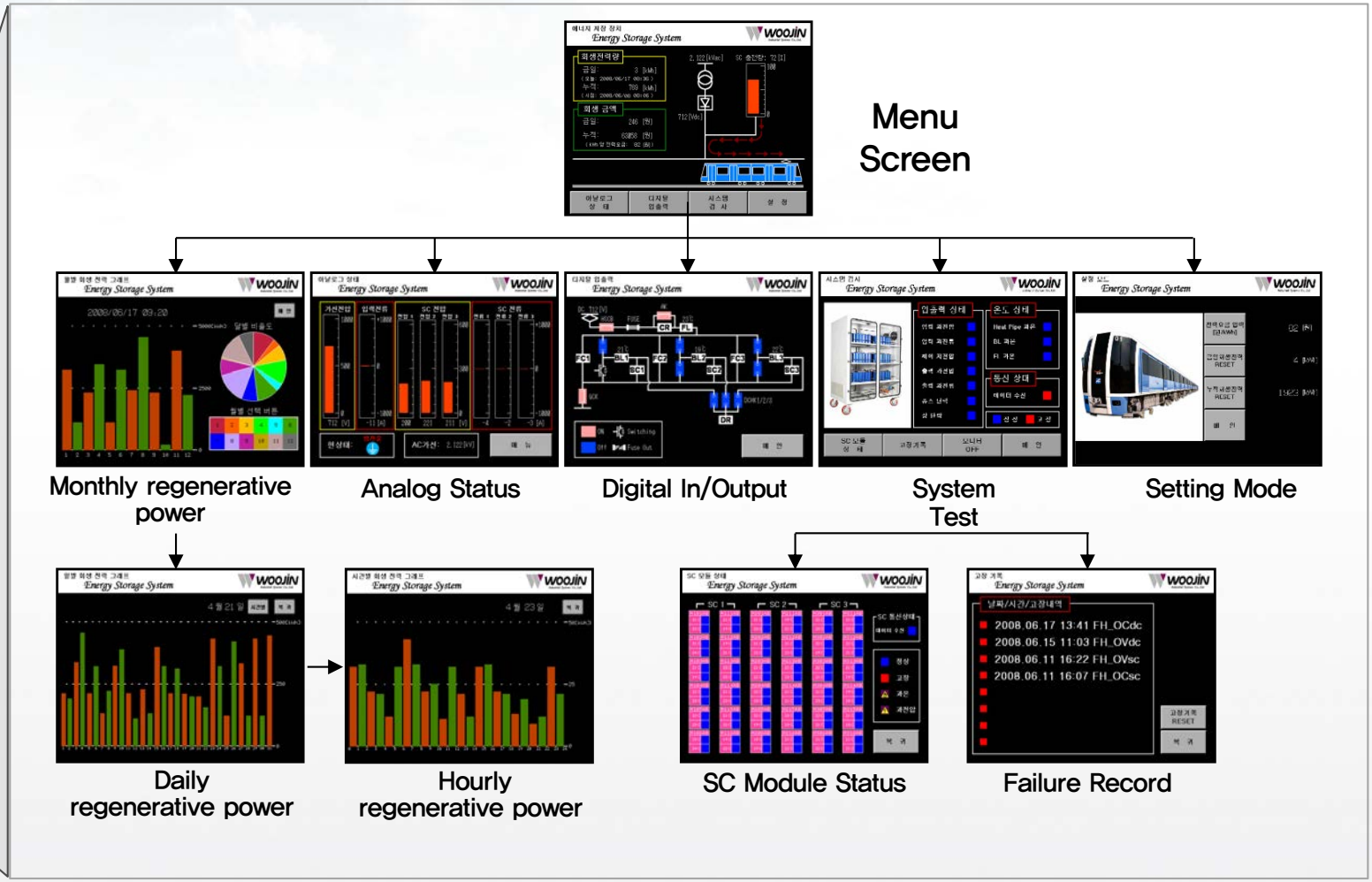
Energy Storage System

Catenary Voltage Sensing Contact Signal Sensing	Optical Communication Module	Remote Control Program	ESS Controller
			

Energy Storage System

3. Characteristic of Energy Storage System

Main Monitoring Interface(MMI) provides our Energy Storage System
with operating friendly environment.



III. Application

1. Application
2. Results

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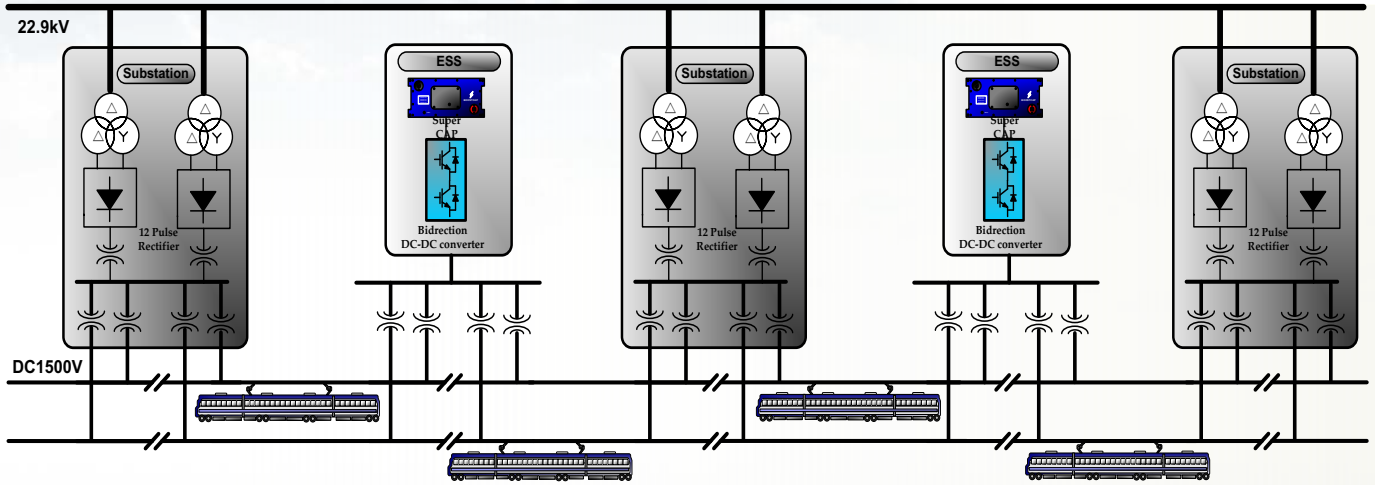
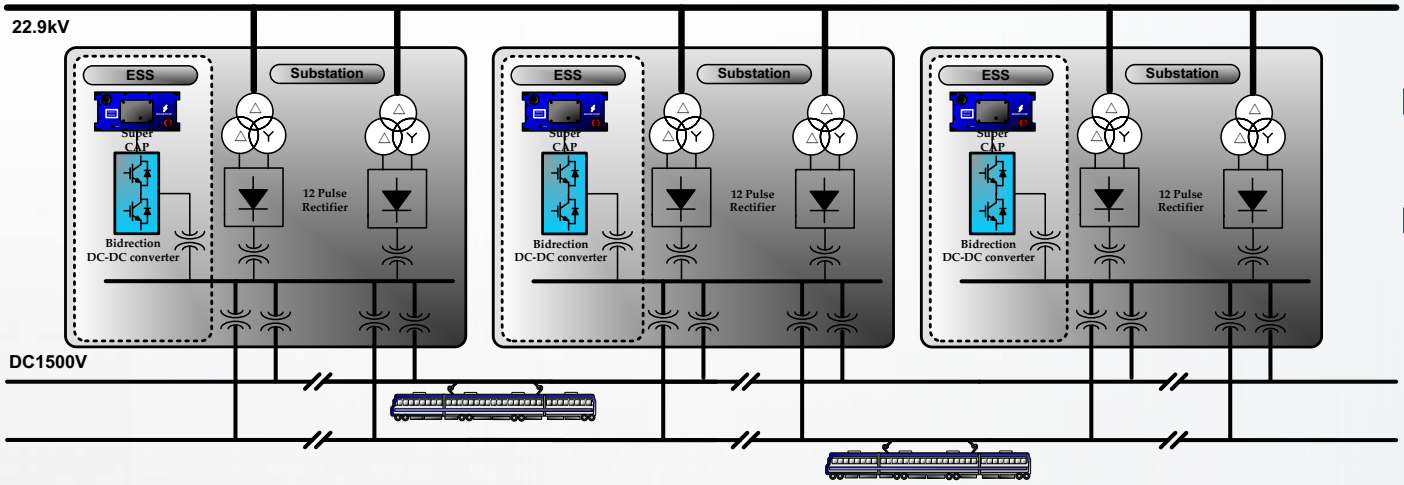
Two ways to install Energy Storage System



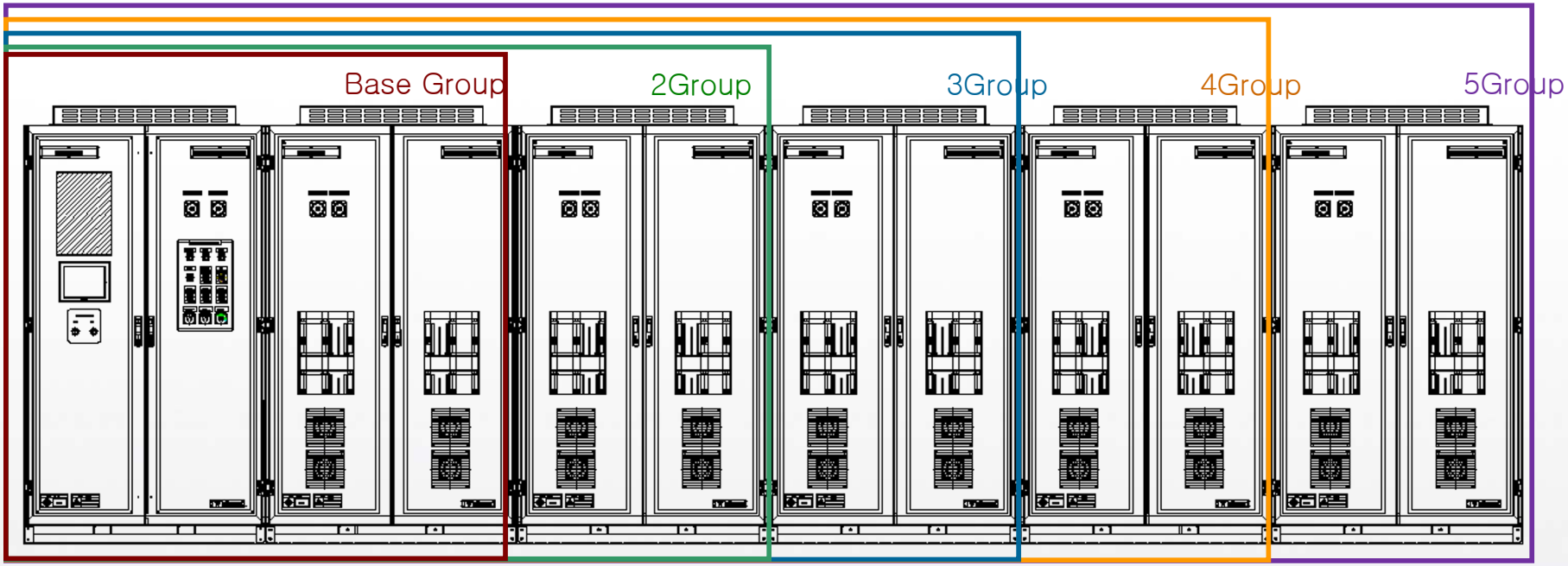
- Shortage of Substation Power Supply
- Dropped Catenary Voltage Compensation
- Hybrid sub-station



- Decrease additional facility cost of substation
- Decrease substation installation cost when basic designing of new route

1. Application – Composition of E.S.S

ITEM		Composition of ESS				
		Base Group	2 Group	3 Group	4 Group	5 Group
Main Box		1	1	1	1	1
Chopper Box		1	2	3	4	5
Rating Capacity	DC 1,500V	7 [MJ]	14 [MJ]	21 [MJ]	28 [MJ]	35 [MJ]
	DC 750V	3.5 [MJ]	7 [MJ]	10.5 [MJ]	14 [MJ]	17.5 [MJ]
Size	DC 1,500V	2.7m(W)×2m(D)×2.4m(H)	4m(W)×2m(D)×2.4m(H)	5.4m(W)×2m(D)×2.4m(H)	6.7m(W)×2m(D)×2.4m(H)	8.1m(W)×2m(D)×2.4m(H)
	DC 750V	2.6m(W)×1.3m(D)×2m(H)	3.9m(W)×1.3m(D)×2m(H)	5.2m(W)×1.3m(D)×2m(H)	6.5m(W)×1.3m(D)×2m(H)	7.8m(W)×1.3m(D)×2m(H)



1. Application – Supply reference

System	User	Completion Date	Location	Capacity
DC 750V LINE	Korea Railroad Research Institute	Sep. 2008	Gyeongsan LRT Test line, Korea	10.52 [MJ]
DC 1,500V LINE	Korea Railroad Research Institute (Prototype of R&D Project)	Aug. 2009	Daedong S/S Daejeon line 1, Korea	37.39 [MJ]
	Daejeon Metro Corporation	Dec. 2010	Cityhall/Gabcheon S/S Daejeon line 1, Korea	28.04 [MJ]
	Seoul Metro Corporation	Aug. 2011	Sangdong S/S on Seoul line 7, Korea	37.39 [MJ]
	Seoul Metro Corporation	Dec. 2012	Seocho S/S on Seoul line 2, Korea	46.73 [MJ]
	Incheon Metro Corporation	Dec. 2012	Techno-park S/S on Incheon line 1, Korea	46.73 [MJ]
	Daegu Metro Corporation	Jun. 2013	Jukjeon S/S on Daegu line 2, Korea	21.03 [MJ]
	Seoul Metro Corporation	Jan. 2014	Ssangmun S/S on Seoul line 4, Korea	46.73 [MJ]
AC 55,000V	Korail	Dec. 2009	KORAIL KTX YongJong S/P, Korea	42.06 [MJ]
DC 750V LINE	Incheon Metro Corporation	Completion by 2014	Depot and other 5 S/S on Incheon line 2, Korea	10.52 [MJ]
DC 1,500V LINE	Seoul Metro Corporation	Completion by 2014	#929 S/S on Seoul line 9, Korea	37.39 [MJ]

1. Application –Gyeongsan LRV test line (DC 750V)

The box of Energy Storage System

Installation (Gyeongsan LRV test line)

Specifications

Max. Voltage	583.2 [V]
Max. Current	1,200 [A]
Max. Capacity	10.5 [MJ] (82.5 [F])
Max. Power	525 [kW] (during 20 [sec])

1. Application – DC 1500V

City hall Substation

Gabcheon Substation

Operating ESS (City hall Substation)

Specifications

Max. Voltage of EDLC tolerance	1,166 [V]
Max. Current of EDLC tolerance	1,200 [A]
Max. Capacity	28.04 [MJ] (41.25 [F])
Max. Power	1.40 [MW] (during 20 [sec])

1. Application – DC 1500V

Seocho Substation

Techno-park Substation

#756 Substation

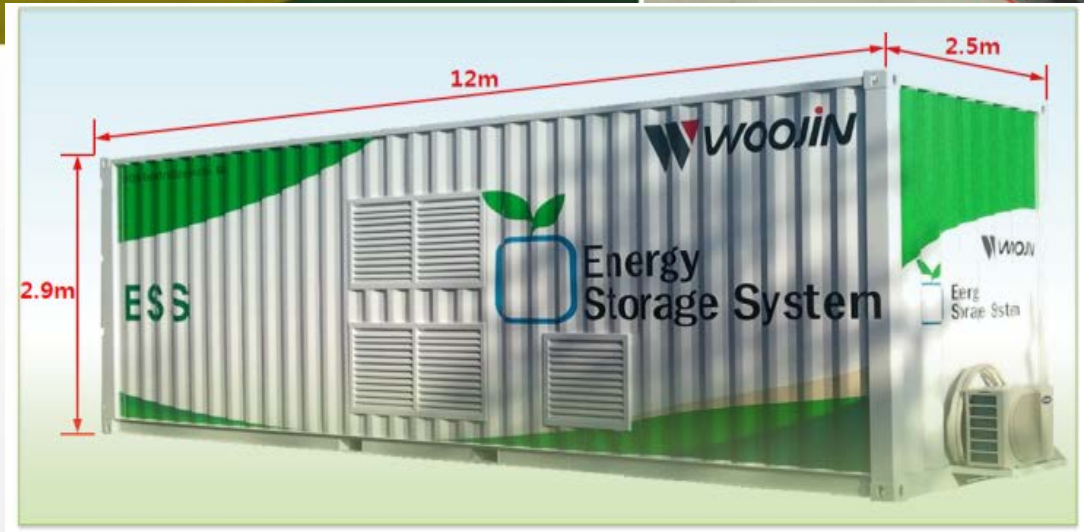
Specifications

	#756 S/S	Seocho/Techno-park S/S
Max. Voltage of EDLC tolerance	1,166 [V]	1,166 [V]
Max. Current of EDLC tolerance	1,800 [A]	2,000 [A]
Max. Capacity	37.39 [MJ] (55.0 [F])	46.73 [MJ] (68.75 [F])
Max. Power	1.87 [MW] (during 20 [sec])	2.34 [MW] (during 20 [sec])

1.1. Installation Type

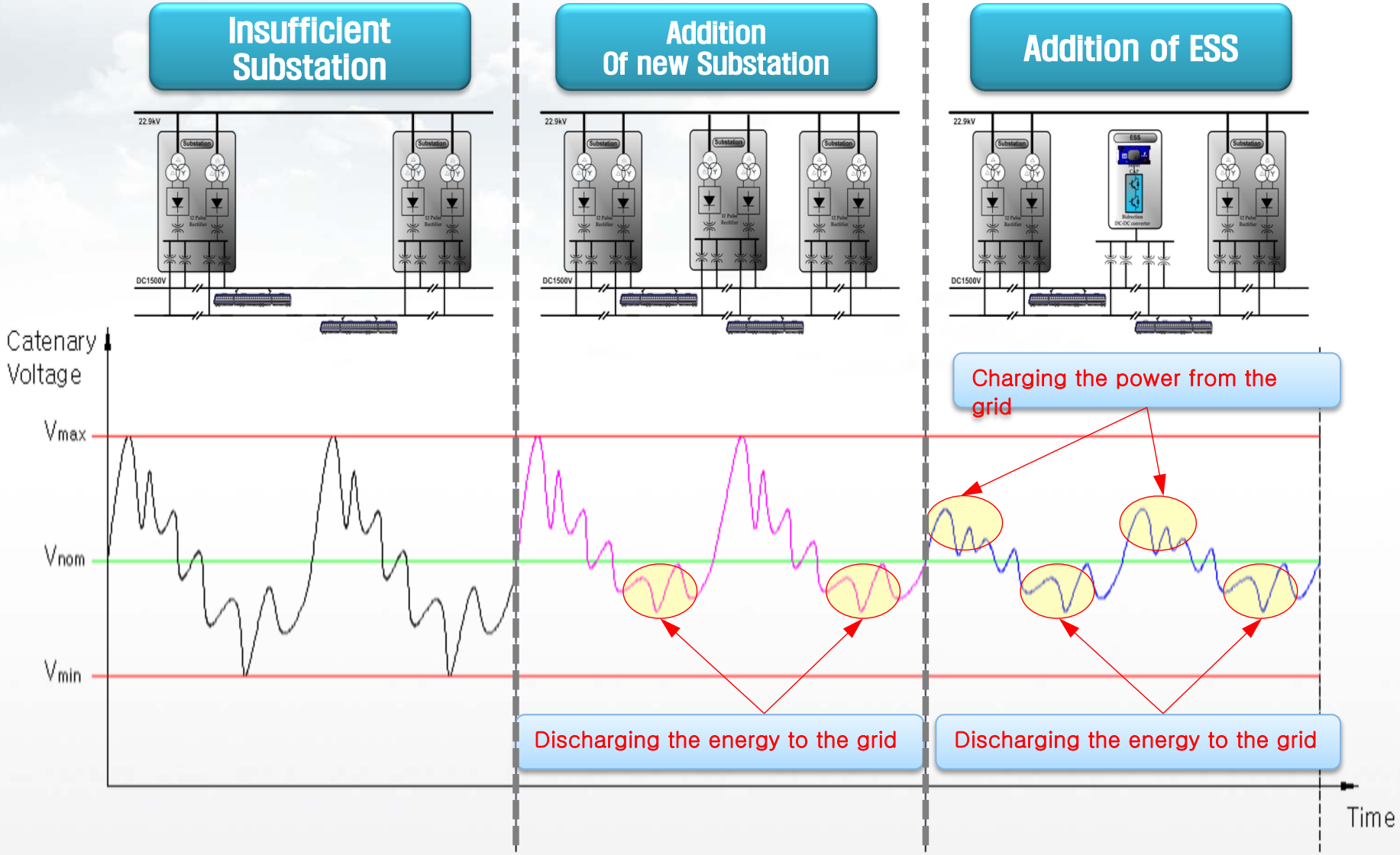
Indoor

Outdoor Structure



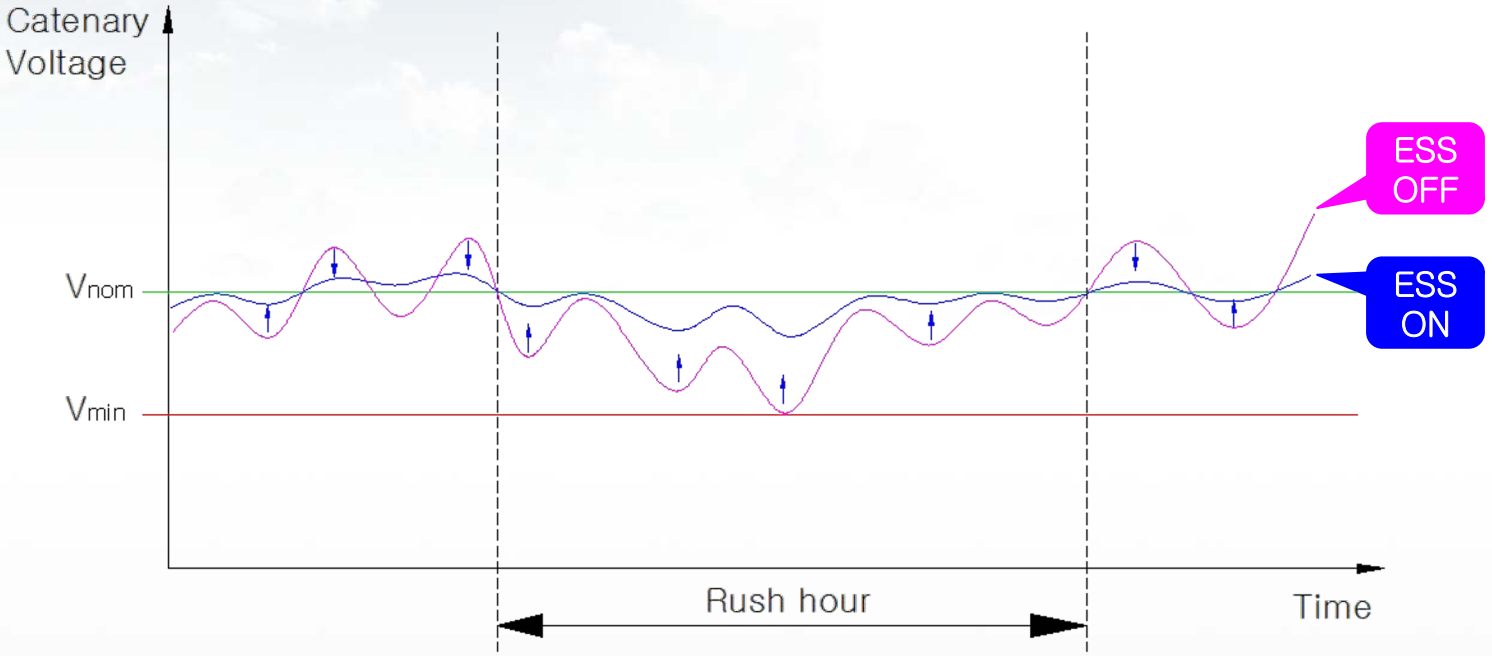
Outdoor Container

2. Results – Stabilization of Catenary



2. Results – Stabilization of Catenary

Catenary Voltage Stabilization Effect



The ESS will store and supply the regenerative energy, continuously, using the measured catenary voltage in real time to supply the stabilized power to Trains for its highest performance.

2.1. Effects Analysis – Seoul Line7 SangDong Substation

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Description		Measured Value in Substation	I-Smart Value		Measured Value in ESS	Average
			24 hours	EMU operating Time		
Average Power Consumption on Catenary per day (kWh)	CESS Off	9,560	9,590	9,096	N/A	-
	CESS On	7,866	7,941	7,481	1,665 (Average of Discharging Power per day)	-
Energy Saving per day (kWh)		1,694	1,649	1,615	1,665	1,656
Rate of Energy Saving (%)		17.72	17.20	17.76	17.42 (*)	17.52

Note) (*) : 1,665 kW / 9,560 x 100(%) = 17.42

1) Capacity of CESS : 32MJ(=1.6 MWx20sec) for DC1500V(DC1650V) Line

2) Charging Starting Voltage : DC 1,725V, Discharging Starting Voltage : DC 1,595V

→ Passive Voltage Control Algorithm -> Advanced Line Voltage Tracking Algorithm

3) Train : 8-car formation

Description		Measuring Instrument	Measured Value in CESS	Average
Average CESS Discharging Power to Catenary per day (kWh)	CESS On	1,714	1,846	1,780

Note) 1) Charging Starting Voltage : DC 1,595V ~ DC1,650V,
Discharging Starting Voltage : DC 1,540V ~ DC1,590V

Benefits from ESS

1. Achieved Average Energy Saving 1,780 kWh per day
2. Stabilization of Catenary Voltage from 1,300V ~ 1,900V => 1,540V~ 1,650V and gap of fluctuation from 600V => 110V
3. Economic analysis **(Saving Cost will be up to the electricity rate. Below is based on Korean's)**

No.	Item	Formula	Cost
1	Energy Saving Cost	1,780kWH x 0.108AUD/kWH X356	68,437 AUD/Y
2	Miscellaneous	Actual reference of different quantity	
	- Brake Shoe		4,065 AUD/Y
	- Increased lifespan of Electric on-board equipment		23,295 AUD/Y
3	Certified Emission Reduction	1,780kWH x0.424kg/kWH x 0.028AUD/kg X356	7,523 AUD/Y
4	Total	103,320 AUD / Y	

4. Miscellaneous Benefits
   (1) Reduction of Loss of Electric Regenerative Braking
   (2) Increasing of lifetime of Consumable Braking parts and Electric Equipment
   (3) Decreasing of Air Pollution in Tunnel and Passenger Stations
   (4) Increasing of Precision stop under ATO operation

2.1. Effects Analysis – Seoul Line7 SangDong Substation

SEOUL METROPOLITAN GOVERNMENT

Statement of Satisfaction

February 5, 2013

To whom it may concern,

We hereby certify that WOOJIN Industrial Systems Co., Ltd. addressed at 613-6, Bangchuk-ri, Sari-myeon, Goesan-gun, Chungcheongbuk-do, Korea (hereinafter referred to as the "WOOJIN") has designed, manufactured and delivered the following Energy Storage System which is consistent with the required technical specifications. The Energy Storage System delivered for the extension line of Seoul Metro Line 7 is been operating satisfactorily on the performance of energy saving & stabilization of power supply through re-using of EMU's regenerative braking energy, on the quality and on the operational requirements & standards.

Classification	Description
Commodity	Energy Storage System
Location of Installation	Sang-dong substation in Extension line for Seoul Metro Line 7
Quantity	1 set
Completion Date of Delivery	December 31, 2012
Revenue Operation Status of EMU	- Power supply : DC 1,500V - Formation : 8car/train - Schedule : AM 05:30 ~ AM 01:00 (19hours 30minutes) - Operation frequency : 110 times in weekday, 91 times in weekend day & holiday
Specification of Energy Storage System	- Rated capacity : 32MJ - Operation voltage Charging start voltage : 1,725Vdc Discharging start voltage : 1,595Vdc
Effect of Energy Storage System	- Daily average of energy saving capacity : 1,656kWh - Daily average of energy saving rate : 17.52% *The effect was measured from January 7, 2013 to January 18, 2013.
Employer	Organization : Seoul Metropolitan Infrastructure Headquarters Address : Sunhwa Bldg. 11th FL, 54 Seosomun-ro, Jung-gu, Seoul 100731, Korea Telephone No. : +82 2 772 7061 Fax No. : +82 2 772 7304

서울특별시 도시기반시설본부장

서울특별시 도시기반시설본부장인 (도서실도국 민원전용)

CHO, SUNG-IL
Deputy Mayor for Seoul Metropolitan Infrastructure Headquarters

Energy Storage System

Amount of Energy Saving in CESS

Existing Passive Voltage Control Algorithm(per day)	Advanced Active Voltage Control Algorithm(per day)		
	Date	Energy Saving in CESS(kWh)	Average(kWh)
1,295kWh	2013.10.24(Thu)	2,832	2,742
	2013.10.25(Fri)	2,709	
	2013.10.26(Sat)	2,629	
	2013.10.27(Sun)	2,769	

Note) 1) Capacity of CESS : 35MJ(=1.75 MWx20sec) for DC1500V(DC1650V) Line
2) ALVT(Advanced Line Voltage Tracking) & ASCVT(Adapted SuperCap Voltage Tracking) Algorithm
→ Applied above Active Voltage Control Algorithm into CESS to increase the amount of Charging/Discharging Energy
3) Train : 10-car formation

Stabilization of Catenary Voltage

Status of ESS	Status of Train	Fluctuation of Catenary Voltage(V)	Gap of Fluctuation(V)
ESS Off	Powering	1410 – 1600	425
	Braking	1645 – 1835	
ESS On	Powering	1520 – 1620	200
	Braking	1665 - 1750	

Benefits from ESS

1. Achieved Average Energy Saving of 2,742 kWh/day
2. Stabilization of Catenary Voltage as gap of fluctuation from 425V => 200V
3. Economic analysis **(Saving Cost will be up to the electricity rate. Below is based on Korean's)**

No.	Item	Formula	Cost
1	Energy Saving Cost	2,742kWH x 0.108AUD/kWH X356	105,425 AUD/Y
2	Miscellaneous	Actual reference of different quantity	
	- Brake Shoe		7,900 AUD/Y
	- Increased lifespan of Electric on-board equipment		25,500 AUD/Y
3	Certified Emission Reduction	2,742kWH x0.424kg/kWH x 0.028AUD/kg X356	11,589 AUD/Y
4	Total	150,414 AUD / Y	

4. Miscellaneous Benefits
   (1) Reduction of Loss of Electric Regenerative Braking
   (2) Increasing of lifetime of Consumable Braking parts and Electric equipment
   (3) Decreasing of Air Pollution in Tunnel and Passenger Stations
   (4) Increasing of Precision stop under ATO operation

IV. Conclusion

1. Conclusion

WOOJIN

The Energy Storage System is the high-tech eco-friendly system

Energy saving

- Reduction of peak power
- Reduction of power cost

Catenary voltage stabilization

- Recycling Regeneration power generated during Braking

Environment protection

- Reduction of CO_2 emission
- Improving the air quality in tunnels

Maintenance costs reduction

- Reduction of the attrition rate of braking parts
- Extension of lifetime of on-board equipment

2. Certificates

New Tech. Certificate

신 기 술 인 증 서

기 술 명 전기철도 제동에너지 저장시스템 개발기술

회 사 명 한국철도기술연구원/(주)우진산전

소 재 지 경기 의왕시 월암동 360-1

인증번호 제0373호

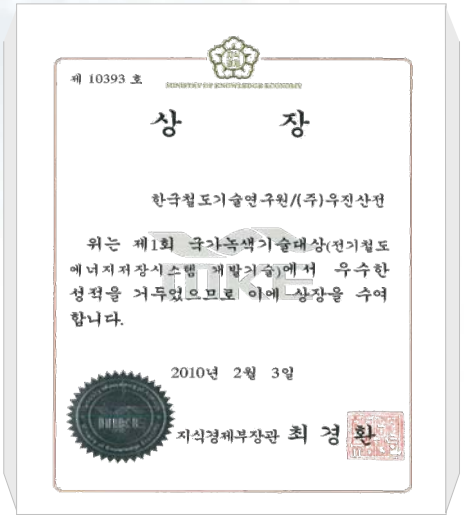
유효기간 2009년 12월 23일~2012년 12월 22일(3년간)

위의 기술은 「기술개발촉진법」 제6조제2항에 따라 신기술임을 인증합니다.

2009년 12월 23일

지식경제부장관

Green Tech. Grand Prize



제 10393 호

상 장

한국철도기술연구원/(주)우진산전

위는 제1회 국가녹색기술대상(전기철도 에너지저장시스템 개발기술)에서 우수한 성적을 거두었으므로 이에 상장을 수여합니다.

2010년 2월 3일

지식경제부장관 최 경 환

Green Certification

녹색기술 인증서

인증번호 : 제 GT-11-00257호
기 관 명 : (주)우진산전
대표자명 : 김 영 창
주 소 : 충북 괴산군 사리면 방축리 613-6
기술명칭 : 전기철도 에너지 저장시스템 기술
분류번호 : T050501

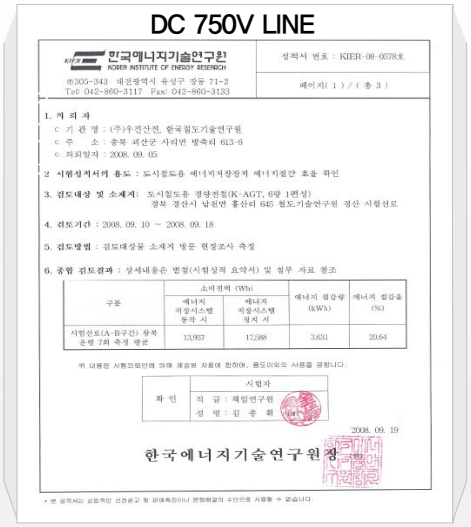
『저탄소 녹색성장 기본법』 제32조 및
『녹색인증제 운영요령』 제27조에 의거하여
위의 기술을 녹색기술로 인증합니다.

인증일자 : 2011.11.24
유효기간 : 2011.11.24~2013.11.23

국 토 해 양 부 장

Test Report for Energy Savings

DC 750V LINE



한국에너지기술연구원 KOREA INSTITUTE OF ENERGY RESEARCH

성적서 번호 : KIER-08-0578호

1. 의 뢰 자
2. 시험성적서의 용도 : 도시철도용 에너지저장장치 에너지절감 효율 확인
3. 검토대상 및 소재지 : 도시철도용 전량전철(K-AGT, 6량 1편성)
4. 검토기간 : 2008. 09. 10 ~ 2008. 09. 18
5. 검토방법 : 검토대상물 소재지 방문 현장조사 측정
6. 종합 검토결과 : 상세내용은 별첨(시험성적 요약서) 및 첨부 자료 참조

구분	소비전력 (Wh)		에너지 절감량 (kWh)	에너지 절감율 (%)
	에너지 저장시스템 동작 시	에너지 저장시스템 정지 시		
시험선로(A-B구간) 왕복 운행 7회 측정 평균	13,957	17,588	3,631	20.64

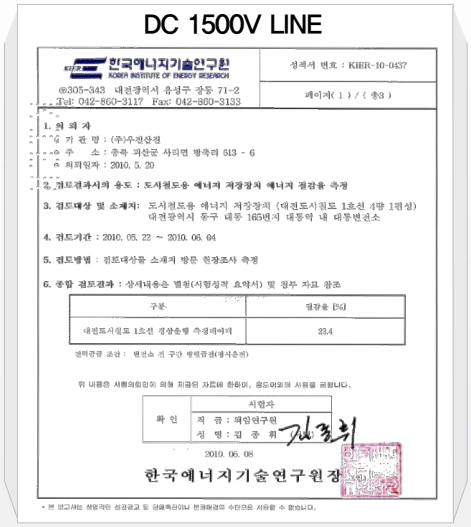
위 내용은 시험의뢰인에 의해 제공된 자료에 한하며, 용도이외의 사용을 금합니다.

확 인 | 시험자 | 직 급 : 책임연구원 | 성 명 : 김 종 휘

2008. 09. 19

한국에너지기술연구원장

DC 1500V LINE



한국에너지기술연구원 KOREA INSTITUTE OF ENERGY RESEARCH

성적서 번호 : KIER-10-0437

1. 의 뢰 자
2. 검토결과서의 용도 : 도시철도용 에너지 저장장치 에너지 절감율 측정
3. 검토대상 및 소재지 : 도시철도용 에너지 저장장치 (대전도시철도 1호선 4량 1편성) 대전광역시 동구 대동 165번지 대동변전소
4. 검토기간 : 2010. 05. 22 ~ 2010. 06. 04
5. 검토방법 : 검토대상물 소재지 방문 현장조사 측정
6. 종합 검토결과 : 상세내용은 별첨(시험성적 요약서) 및 첨부 자료 참조

구분	절감율 [%]
대전도시철도 1호선 정상운행 측정데이터	23.4

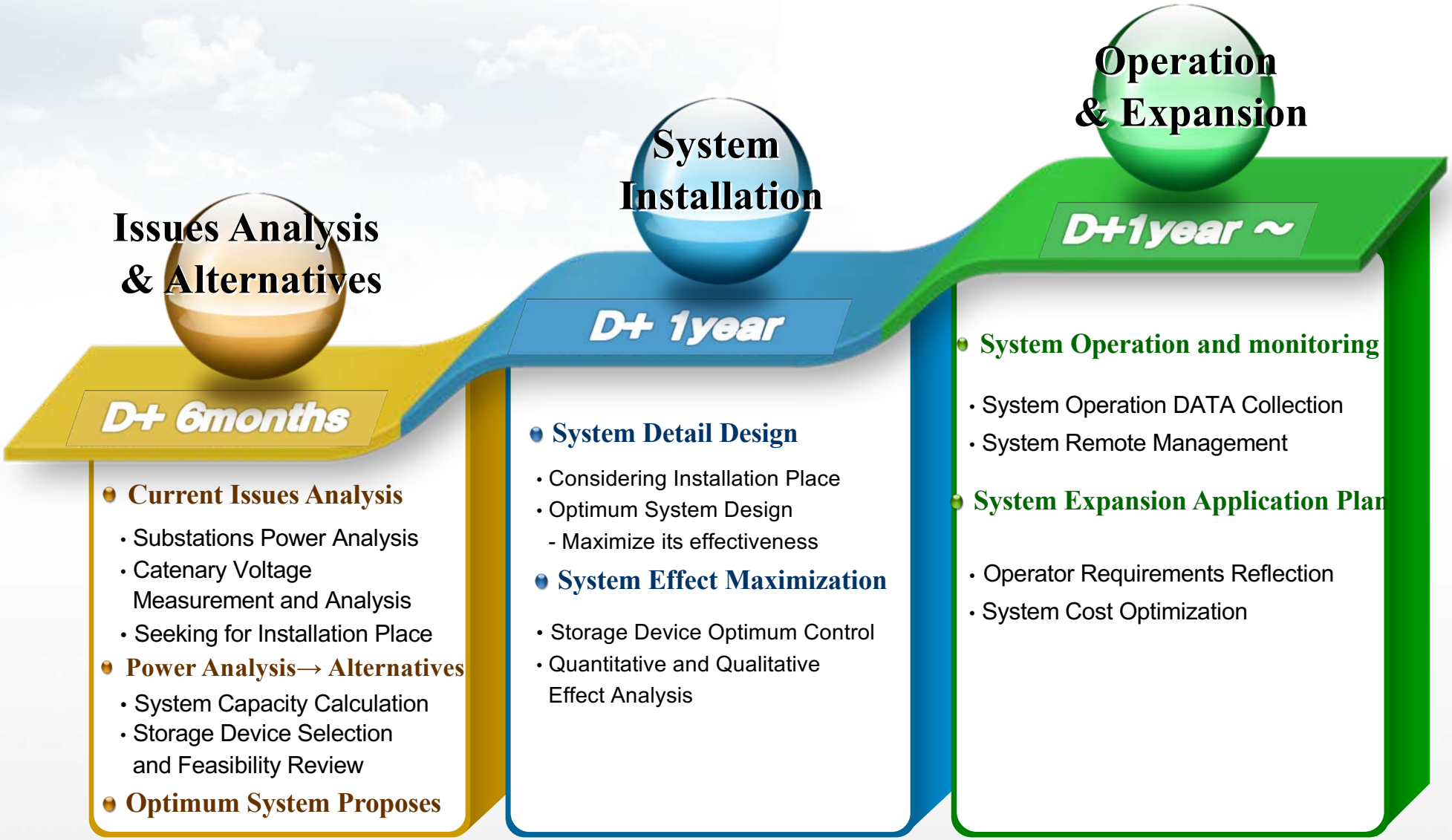
위 내용은 시험의뢰인의 의해 제공된 자료에 한하며, 용도이외의 사용을 금합니다.

확 인 | 시험자 | 직 급 : 책임연구원 | 성 명 : 김 종 휘

2010. 06. 08

한국에너지기술연구원장

3. Milestones



Thank you