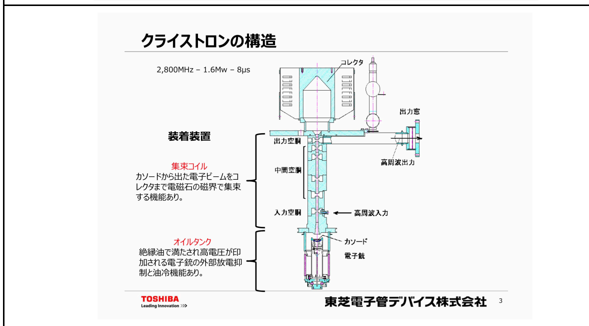
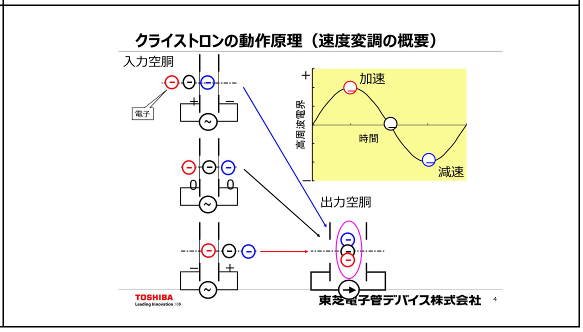
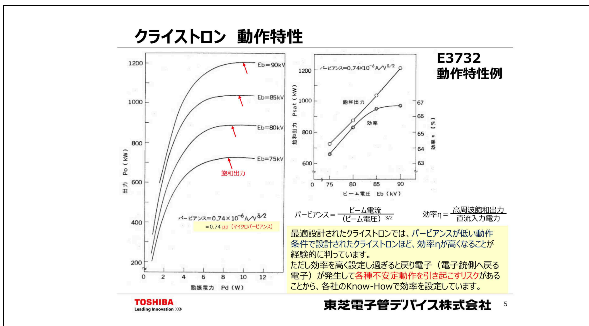
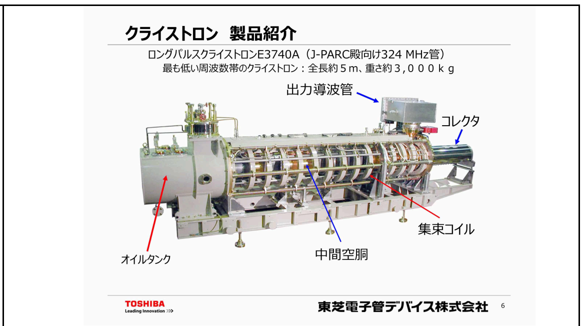
4 Energy Saving Technology of Accelerator Device

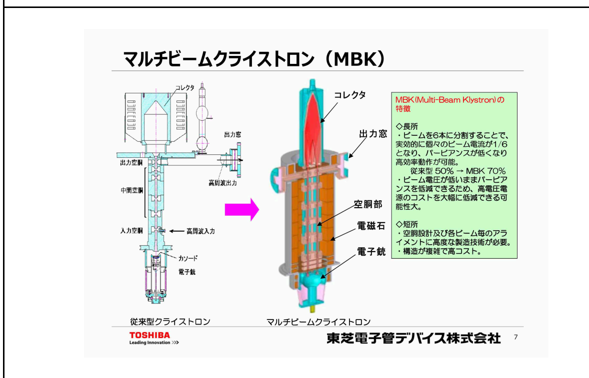
Collector Power Depression (CPD) Klystron
(Yoshio Kawakami, Toshiba-Electrontube)

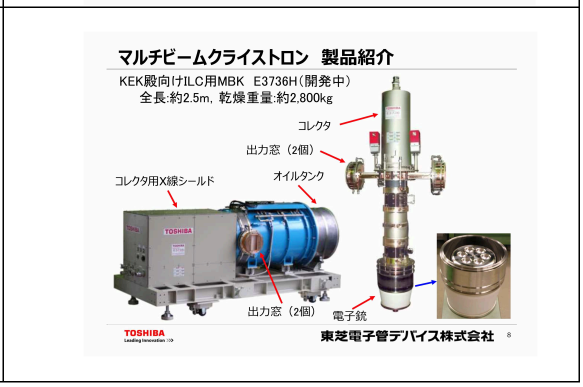






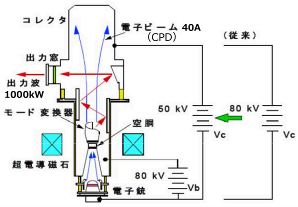






コレクタ電位降下型（Collector Potential Depression）の原理

左下図の核融合研究用ジャイロトロンでCPDの原理を説明します。
CPDの場合、電子ビームから出力波（高周波出力電力）のエネルギーを取り出し後の電子ビームは 50kV－80kV=－30kV の電圧差で減速されてコレクタに入射します。
効率の定義式から、CPDの場合は従来の場合より約20%も効率が向上します。



◇効率ηの定義

$$効率\eta = \frac{高周波飽和出力}{直流入力電力}$$

＊従来の場合

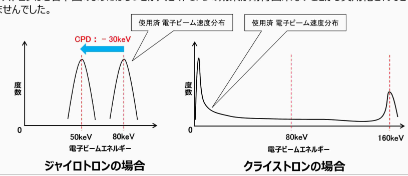
$$31\% = \frac{1000kW}{80kV \times 40A}$$

＊CPDの場合

$$50\% = \frac{1000kW}{50kV \times 40A}$$

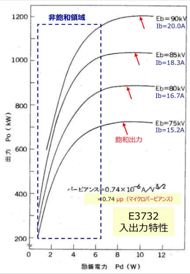
CPDによる効率向上

ジャイロトロンは動作原理上、管軸に対して回転方向の電子ビームエネルギーを高周波エネルギーに変換する電子管であり、管軸方向の電子ビームを利用していません。
そのため左下図のように、管軸方向の使用済電子ビーム速度分布はばらつきが小さいままであり、CPD（一定値のマイナス電位）による電子の速度低減効果で効率向上に寄与します。
一方、クライストロンは動作原理上、管軸方向の電子ビームエネルギーを高周波エネルギーに変換する電子管であり、高周波エネルギーを取り出した使用済電子ビーム速度分布は効率が高いクライストロンほど右下図のようにばらつきが大きく、CPDの効果が期待出来ないことから実用化されてきませんでした。

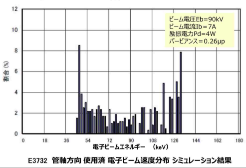


ジャイロトロンの場合　　クライストロンの場合

CPDクライストロン 電子ビーム速度分布検討



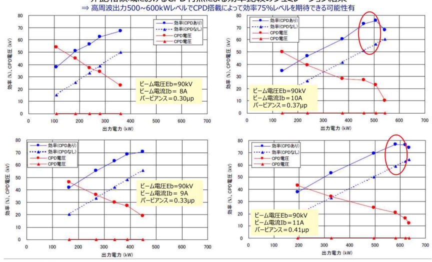
加速器によっては左図の飽和出力を出している時間よりも、非飽和領域でクライストロンを使用している時間が長い場合が想定されます。その場合、ビーム電圧が高い条件のままビーム電流だけを下げて動作できるクライストロン（モジュレーションアノード型）であれば、高周波エネルギーを取り出した使用済電子ビーム速度分布がそれほど広がらない場合を想定できることから、CPDの効果を発揮できる可能性があります。
非飽和領域における使用済電子ビーム速度分布をシミュレーションした結果の一例を下図に示します。前頁の速度分布に比較してかなりばらつきが小さくなっていることが判ります。



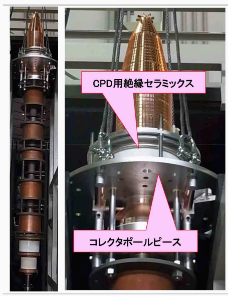
E3732 管軸方向 使用済 電子ビーム速度分布 シミュレーション結果

CPDクライストロン 効率シミュレーション結果

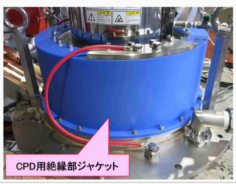
非飽和領域におけるCPD有無による効率比較のシュミレーション結果
⇒ 高周波出力500~600kWレベルでCPD搭載によって効率75%レベルを期待できる可能性有



実験用CPDクライストロンE37703の紹介

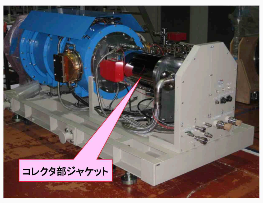


CPD効果確認用としてE3732のコレクタをCPD化した実験用CPDクライストロンE37703を動作試験なしでKEK殿に納入しました。
コレクタを電気的に絶縁するためにセラミックス部品を使用し、そのセラミックス部品を冷却するために絶縁部ジャケット内はフロリナートで充填され、更にフロリナートを冷却するために冷却水を流すテフロンチューブがジャケット内側に2重に巻かれているなど、非常に複雑な構造となっています。



ILC用MBKへのCPD技術適用の可能性

ILC用MBKは、非飽和領域で使用すると伺っていますので、CPD実験管E37703で良い結果が得られれば、CPD技術を適用した場合の費用対効果を評価する意義はあるものと考えます。



ILC用CPD-MBKの製造メーカとしての主な課題は以下と考えています。

＊真空管内部の構造が既に十分に複雑なMBKに対して、更に構造が複雑になるCPD型コレクタを搭載した構造設計が出来ること。

＊左写真はMBKのコレクタ側カバーを取り外した状態であり、既に十分に複雑なコレクタ部ジャケット近傍に、更にCPD用絶縁部ジャケットを追加して、コレクタ部の電気絶縁とCPD部の冷却機能を両立させた外装部の構造設計が出来ること。

＊CPD用絶縁部からの漏えい電力を外へ漏らさない外装カバーの構造設計が出来ること。

TOSHIBA
Leading Innovation >>>

Operation test of CPD klystron
(Ken Watanabe, KEK)

CPD（コレクタ電位降下型）クライストロンの動作試験について

高エネルギー加速器研究機構　加速器研究施設
第三研究系　渡邉　謙

先端加速器科学技術推進協議会(AAA)
第3回グリーンILC WG
2014年7月1日(火)　 20min+10min　=30min

1

はじめに

・本報告は、先日行われた第2回グリーンILC WGで発表された

「コレクタ電位降下型(CPD)クライストロン」 ：　東芝電子管デバイス　川上氏

　の続きとなり、製作した本クライストロンのKEKにおける動作試験の準備状況および試験プランについて報告するものである。

・クライストロンの動作原理などついては、先の報告を参照のこと。

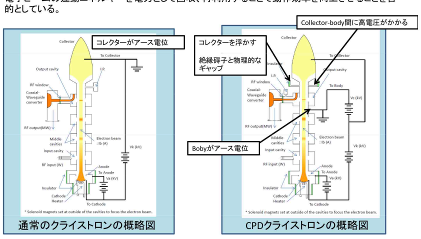
・本試験はクライストロンへのCPD方式の適用、これの原理実証を目的としている。
　コレクターへ入射された電子ビームから電力回収できるという原理実証までが試験の範疇である。取り出された電力は、ダミー抵抗器などで吸収する。
なお、本クライストロンはCWで運転するものである。パルス動作のものとは異なる点が多い。

最終的には回収電力をクライストロン電源へ戻し、再利用することを行う必要があるが、それは本報告の範疇では無い。今後の課題である。

2

クライストロンへのCPD方式の適用(1)

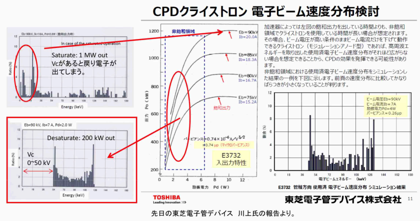
・CPD (Collector Potential Depression) クライストロンでは、コレクターへ入射され、熱に変換される電子ビームの運動エネルギーを電力として回収、再利用することで動作効率を向上させることを目的としている。



3

クライストロンへのCPD方式の適用(2)

CW(連続波)運転のクライストロンの稼働に際しては、リニア領域(ドライブで出力を制限)での稼働となる事が多い(逆に飽和領域での稼働はしない/出来ない)。このことがCPD方式の検討を開始した要因の一つである。
飽和で効率70%の球があっても、リニア領域では効率が下がり、実際には55-60%程度での稼働になる。(パルスクライストロンとは状況が異なることを理解)



先日の東芝電子管デバイス　川上氏の報告より。

クライストロンへのCPD方式の適用(3)

クライストロン電源は既存の構成を出来るだけ保持する方式を考える。

以下、再利用する場合に考えられるセットアップ：

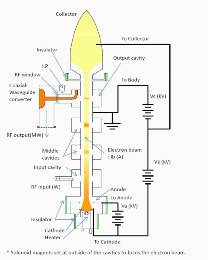
①VkとVcを直列にする「Power=(Vk+Vc)*Ib」

　電源を直列に接続、回収した電力を用いてVcを発生させる。

②並列「Power=Vk*(Ik+Ic)」

　マルクス回路等を用いてVkまで(DC 90kV?)昇圧、再利用する。
今回の原理実証試験ではこの方式を取る。出力は、隣にある別のクライストロンへ入力、ダミーロードとする。

③6.6kV交流(50Hz)へ変換し既存電源の入力とする方式(詳細検討未だ)
　複数のステーションから回収した電力を一か所にまとめて再利用することで、変動は減らせるか？



①VkとVcを直列にする「Power=(Vk+Vc)*Ib」の概念図

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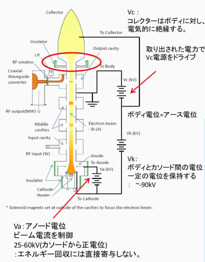
クライストロンへのCPD方式の適用(4)：①の場合



Vc：
コレクターはボディに対し、電気的に絶縁する。

取り出された電力でVc電源をドライブ

ボディ電位=アース電位

Vk：
ボディとカソード間の電位
一定の電位を保持する
：　~-90kV

Va：アノード電位
ビーム電流を制御
25-60kV(カソードから正電位)
：エネルギー回収には直接寄与しない。

クライストロンへのCPD方式の適用
：ボディの電位をアース電位とし、コレクターは絶縁し、電位を発生させて電力回収する。
(CPD電位：両者間に電位を持たせる)

入力電力で作る電位 = カソード電位－CPD電位
稼働に必要な一定のカソード電位を作る為の入力電力はCPD電位分軽減される。
↑
Vk / Vc の割合で効率が改善する
90 kV / 50 kV = 1.8　 (元が30%程度の場合、54%まで改善する)

飽和運転では、電子のエネルギー分布（速度分布）の観点からVcを印加することができない。結果、非飽和の状態でしか適用できない。
CWのクライストロンの稼働に際しては、リニア領域(ドライブで出力を制限)での稼働となることが多い。このことがCPD方式の検討を開始した要因の一つである。

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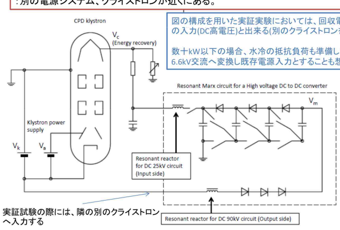
クライストロンへのCPD方式の適用(4)：②の場合

実証試験では、できる限り既存システムと回収電力系を切り離すことを考える。
：電圧変動を経由してバンチングの恐れもあるか？
幸い、別の通常のクライストロンをダミーロードとして使用することが、比較的容易に設定できる状態である。
：別の電源システム、クライストロンが近くにある。

図の構成を用いた実証実験においては、回収電力を別のクライストロンの入力(DC高電圧)と出来る(別のクライストロンをダミーロードとする)。

数十kW以下の場合、水冷の抵抗負荷も準備している。実用の場合には、6.6kV交流へ変換し既存電源入力とすることも想定している(未検討)。



実証試験の際には、隣の別のクライストロンへ入力する

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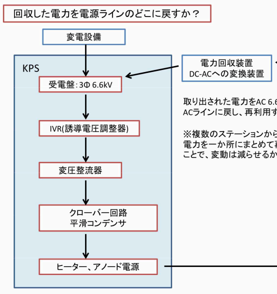
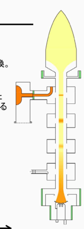
クライストロンへのCPD方式の適用(4)：③の場合

回収した電力を電源ラインのどこに戻すか？



取り出された電力をAC 6.6kVに変換。
ACラインに戻し、再利用する。

※複数のステーションから回収した電力を一か所にまとめて再利用することで、変動は減らせるか？



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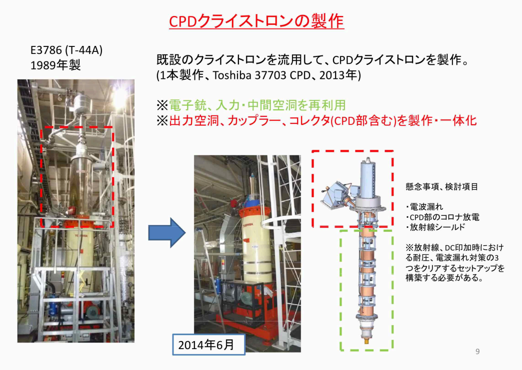
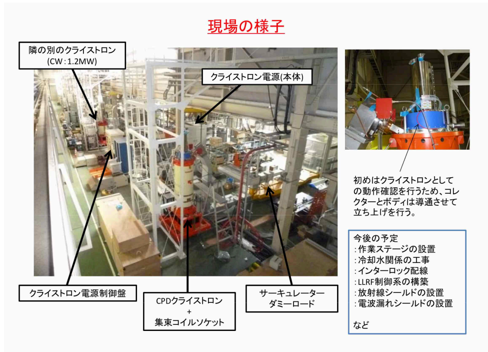
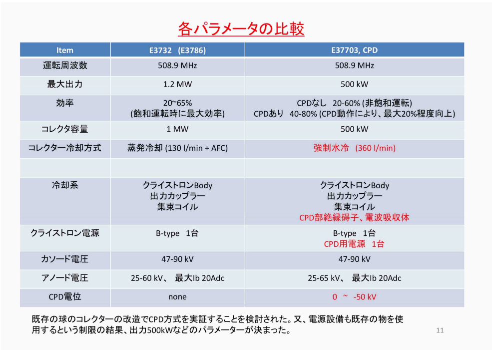
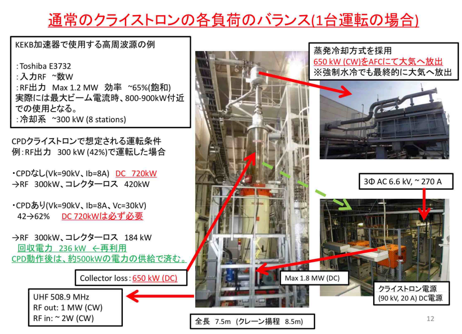
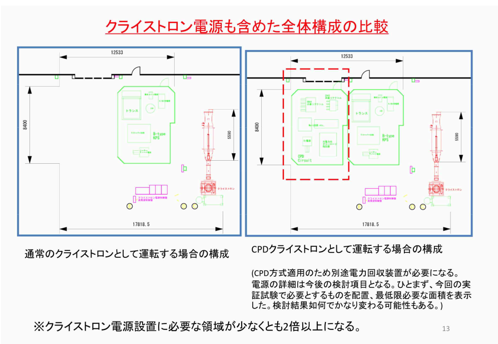


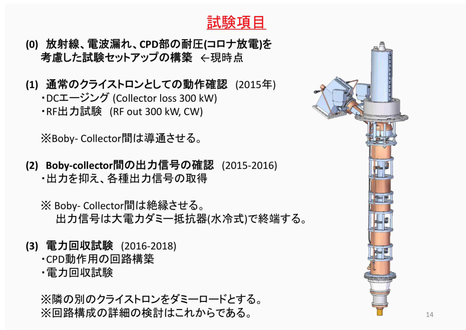


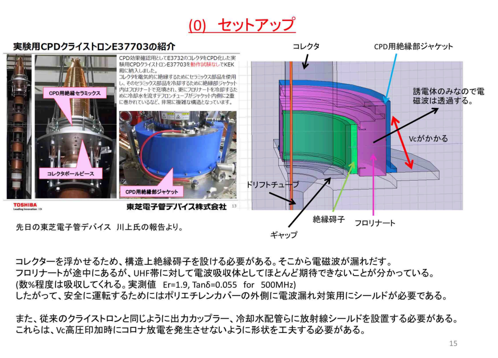


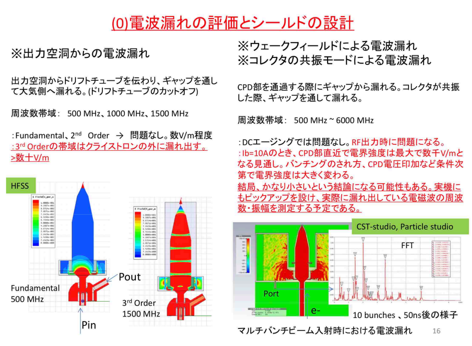
Item	E3732 (E3786)	E37703, CPD
運転周波数	508.9 MHz	508.9 MHz
最大出力	1.2 MW	500 kW
効率	20~65% (飽和運転時に最大効率)	CPDなし 20-60% (非飽和運転) CPDあり 40-80% (CPD動作により、最大20%程度向上)
コレクタ容量	1 MW	500 kW
コレクター冷却方式	蒸発冷却 (130 l/min + AFC)	強制水冷 (360 l/min)
冷却系	クライストロンBody 出力カップラー 集束コイル	クライストロンBody 出力カップラー 集束コイル CPD部絶縁碍子、電波吸収体
クライストロン電源	B-type 1台	B-type 1台 CPD用電源 1台
カソード電圧	47-90 kV	47-90 kV
アノード電圧	25-60 kV、 最大Ib 20Adc	25-65 kV、 最大Ib 20Adc
CPD電位	none	0 ~ -50 kV

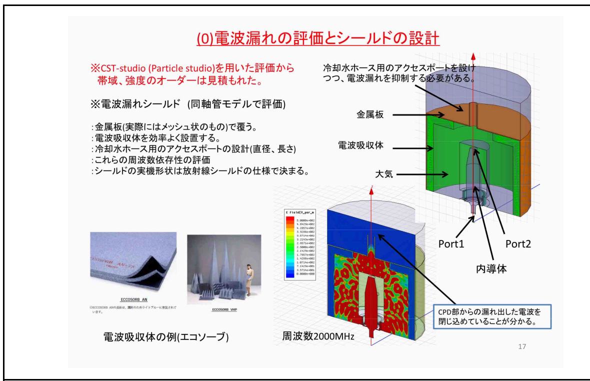


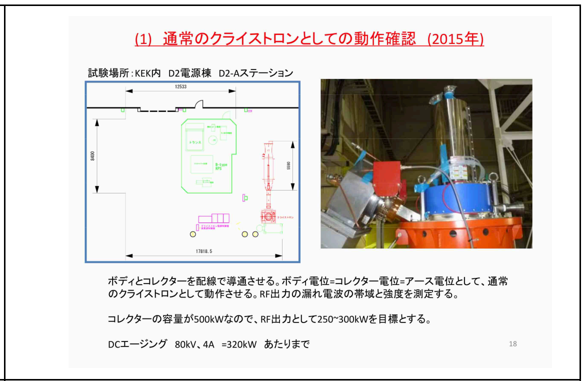


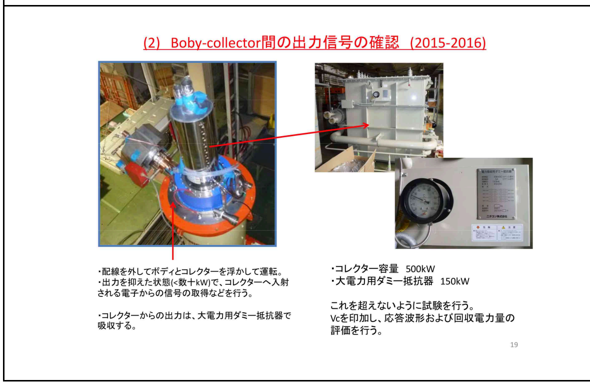


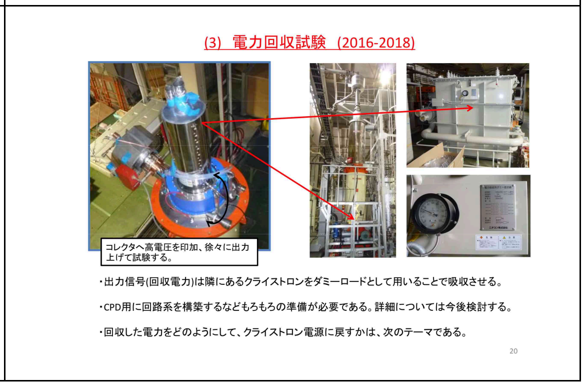


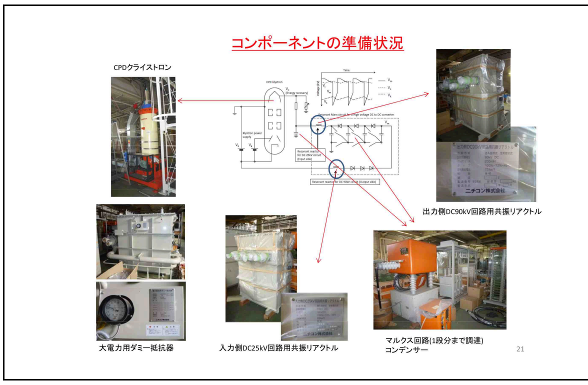


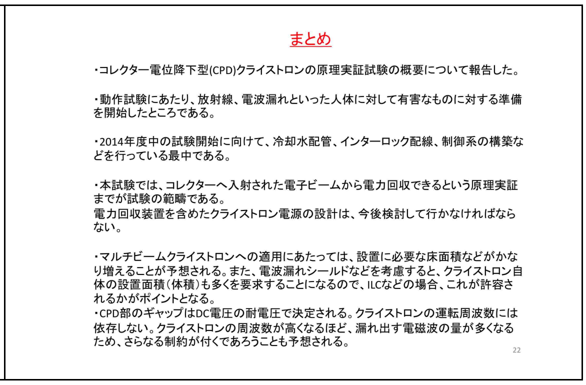

(0)電波漏れの評価とシールドの設計
※CST-studio (Particle studio)を用いた評価から
帯域、強度のオーダーは見積もれた。
※電波漏れシールド (同軸管モデルで評価)
:金属板(実際にはメッシュ状のもの)で覆う。
:電波吸収体を効率よく設置する。
:冷却水ホース用のアクセスポートの設計(直径、長さ)
:これらの周波数依存性の評価
:シールドの実機形状は放射線シールドの仕様で決まる。
冷却水ホース用のアクセスポートを設けつつ、電波漏れを抑制する必要がある。
金属板
電波吸収体
大気
Port1
Port2
内導体
ECCOSORB AN
ECCOSORB VHP
CPD部からの漏れ出した電波を閉じ込めていることが分かる。
電波吸収体の例(エコソーブ)
周波数2000MHz
17


(1) 通常のクライストロンとしての動作確認 (2015年)
試験場所:KEK内 D2電源棟 D2-Aステーション
12533
8400
5590
トランス
B-type KPS
クライストロン
17818.5
ボディとコレクターを配線で導通させる。ボディ電位=コレクター電位=アース電位として、通常のクライストロンとして動作させる。RF出力の漏れ電波の帯域と強度を測定する。
コレクターの容量が500kWなので、RF出力として250~300kWを目標とする。
DCエージング 80kV、4A =320kW あたりまで
18


(2) Boby-collector間の出力信号の確認 (2015-2016)
・配線を外してボディとコレクターを浮かして運転。
・出力を抑えた状態(<数十kW)で、コレクターへ入射される電子からの信号の取得などを行う。
・コレクターからの出力は、大電力用ダミー抵抗器で吸収する。
・コレクター容量 500kW
・大電力用ダミー抵抗器 150kW
これを超えないように試験を行う。
Vcを印加し、応答波形および回収電力量の評価を行う。
19


(3) 電力回収試験 (2016-2018)
コレクタへ高電圧を印加、徐々に出力上げて試験する。
・出力信号(回収電力)は隣にあるクライストロンをダミーロードとして用いることで吸収させる。
・CPD用に回路系を構築するなどもろもろの準備が必要である。詳細については今後検討する。
・回収した電力をどのようにして、クライストロン電源に戻すかは、次のテーマである。
20


コンポーネントの準備状況
CPDクライストロン
出力側DC90kV回路用共振リアクトル
大電力用ダミー抵抗器
入力側DC25kV回路用共振リアクトル
マルクス回路(1段分まで調達)
コンデンサー
21


まとめ
・コレクター電位降下型(CPD)クライストロンの原理実証試験の概要について報告した。
・動作試験にあたり、放射線、電波漏れといった人体に対して有害なものに対する準備を開始したところである。
・2014年度中の試験開始に向けて、冷却水配管、インターロック配線、制御系の構築などを行っている最中である。
・本試験では、コレクターへ入射された電子ビームから電力回収できるという原理実証までが試験の範疇である。
電力回収装置を含めたクライストロン電源の設計は、今後検討して行かなければならない。
・マルチビームクライストロンへの適用にあたっては、設置に必要な床面積などがかなり増えることが予想される。また、電波漏れシールドなどを考慮すると、クライストロン自体の設置面積(体積)も多くを要求することになるので、ILCなどの場合、これが許容されるかがポイントとなる。
・CPD部のギャップはDC電圧の耐電圧で決定される。クライストロンの運転周波数には依存しない。クライストロンの周波数が高くなるほど、漏れ出す電磁波の量が多くなるため、さらなる制約が付くであろうことも予想される。
22

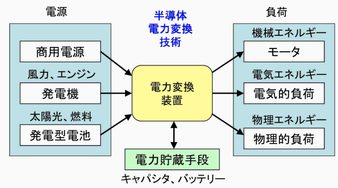
Power electronics technology for power saving power-supplies
(Masaki Yamada, Mitsubishi Electric)

電源系の省エネに貢献する
パワーエレクトロニクス技術

2013年 12月 16日
三菱電機株式会社　山田 正樹

1

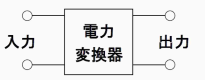
パワーエレクトロニクスとは？



電源、負荷、電力貯蔵手段との間で自由な電力のやり取りを可能にする。
（それぞれの要求に対応した）

2

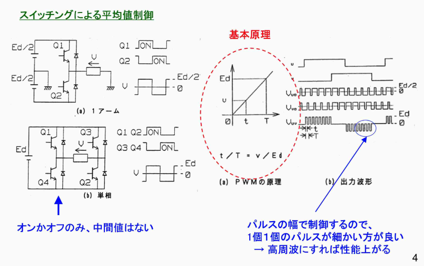
電力変換装置



		入力	
		AC	DC
出力	AC	AC―AC	DC―AC インバータ・逆変換
	DC	AC―DC 順変換	DC―DC

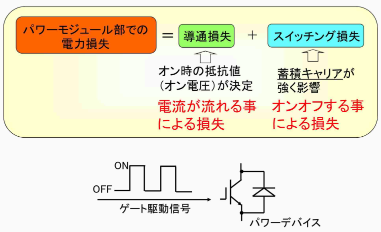
3

パワーエレクトロニクスの基本原理



4

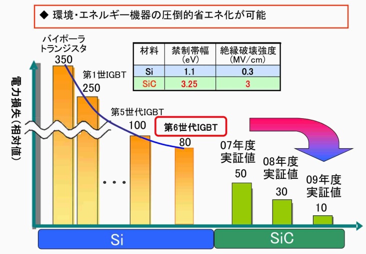
パワーデバイスの電力損失



電力損失の低減には導通損失、スイッチング損失ともに低減が必要

5

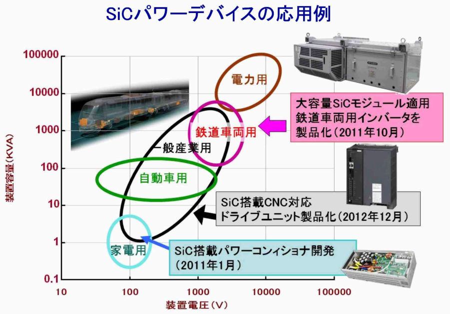
SiCパワーコンバータ



材料	禁制帯幅 (eV)	絶縁破壊強度 (MV/cm)
Si	1.1	0.3
SiC	3.25	3

6

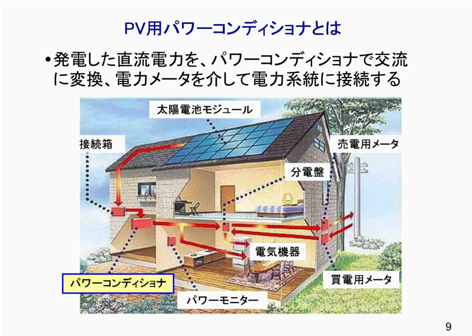
SiCパワーデバイスの応用例



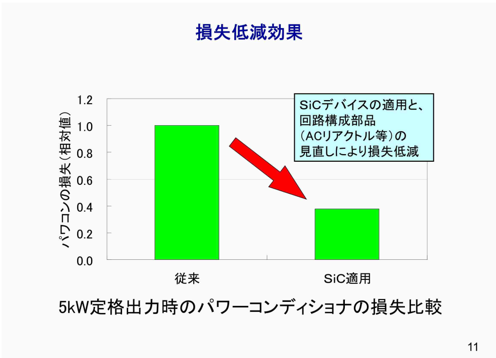
7

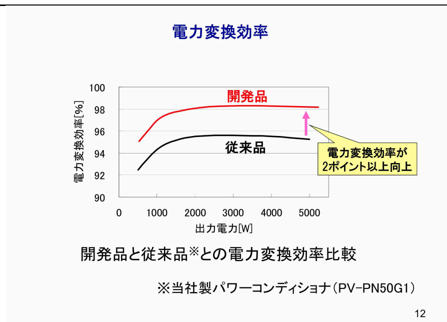
PV用インバータの例

8

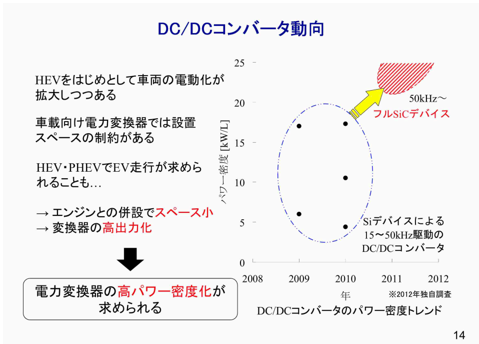

PV用パワーコンディショナとは
•発電した直流電力を、パワーコンディショナで交流に変換、電力メータを介して電力系統に接続する
太陽電池モジュール
接続箱
売電用メータ
分電盤
電気機器
パワーコンディショナ
買電用メータ
パワーモニター
9

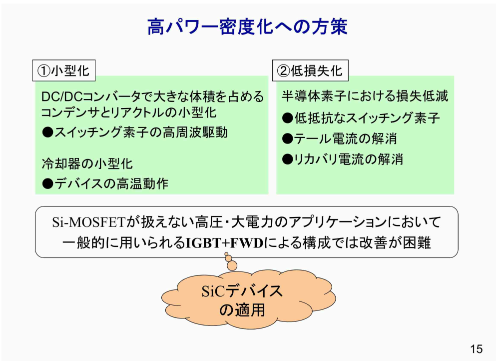

SiCモジュール搭載パワーコンディショナ
単相200V 5kW機種の太陽光パワーコンディショナに
SiC-MOSFET、SiCダイオードを適用したパワーモジュールを搭載し、
変換効率(98%)を達成
SiCパワーモジュールを
パワーコンディショナに搭載
10

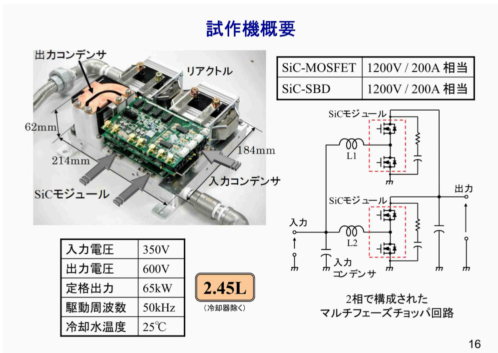

損失低減効果
パワコンの損失(相対値)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
従来
SiC適用
SiCデバイスの適用と、回路構成部品(ACリアクトル等)の見直しにより損失低減
5kW定格出力時のパワーコンディショナの損失比較
11


電力変換効率
電力変換効率[%]
100
98
96
94
92
90
0
1000
2000
3000
4000
5000
出力電力[W]
開発品
従来品
電力変換効率が2ポイント以上向上
開発品と従来品※との電力変換効率比較
※当社製パワーコンディショナ(PV-PN50G1)
12


DC/DCコンバータの例
13


DC/DCコンバータ動向
HEVをはじめとして車両の電動化が拡大しつつある
車載向け電力変換器では設置スペースの制約がある
HEV・PHEVでEV走行が求められることも…
→エンジンとの併設でスペース小
→変換器の高出力化
電力変換器の高パワー密度化が求められる
パワー密度 [kW/L]
25
20
15
10
5
0
2008
2009
2010
2011
2012
年
50kHz〜
フルSiCデバイス
Siデバイスによる
15〜50kHz駆動の
DC/DCコンバータ
※2012年独自調査
DC/DCコンバータのパワー密度トレンド
14

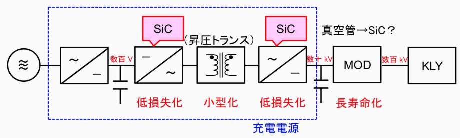

高パワー密度化への方策
①小型化
DC/DCコンバータで大きな体積を占めるコンデンサとリアクトルの小型化
●スイッチング素子の高周波駆動
冷却器の小型化
●デバイスの高温動作
②低損失化
半導体素子における損失低減
●低抵抗なスイッチング素子
●テール電流の解消
●リカバリ電流の解消
Si-MOSFETが扱えない高圧・大電力のアプリケーションにおいて
一般的に用いられるIGBT+FWDによる構成では改善が困難
SiCデバイスの適用
15


試作機概要
出力コンデンサ
リアクトル
62mm
214mm
184mm
入力コンデンサ
SiCモジュール
SiC-MOSFET 1200V / 200A 相当
SiC-SBD 1200V / 200A 相当
入力電圧 350V
出力電圧 600V
定格出力 65kW
駆動周波数 50kHz
冷却水温度 25℃
2.45L
(冷却器除く)
SiCモジュール
L1
L2
出力
入力
入力コンデンサ
2相で構成された
マルチフェーズチョッパ回路
16

加速器用途への展開

17

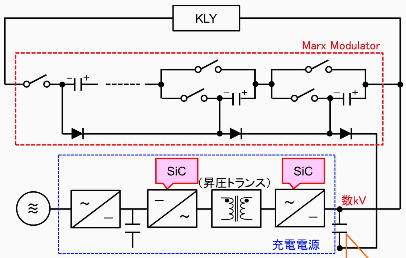
大型加速器システムへの適用時のメリット



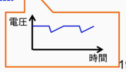
特にモジュレータ入力部のコンデンサ充電電源にメリットが大きい
（1）SiC適用で低損失化
（2）高周波駆動し、昇圧トランスを小型化
（3）高周波駆動し、出力電圧を高精度化

18

長パルスシステム

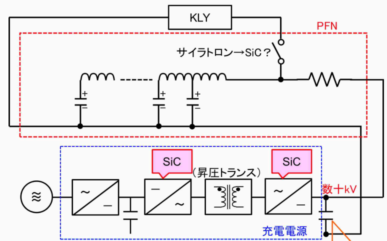


出力電圧 数kVで放電時も直流電圧の変動は
比較的小さい

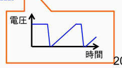


19

短パルスシステム



出力電圧 数十kVで放電時はゼロまで低下
⇒電源としての難易度高



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むすび

- パワー素子の損失低減により、機器の性能向上を実現、特にSiCデバイスの適用により、パワーエレクトロニクス回路を構成するパワー素子の損失を低減
- パワー素子の損失低減効果と共に、機器全体を対象とする最適設計により、システム全体の効率改善を実現
- 加速器用途への展開においては、特に充電電源の低損失・小型化に有効であり、今後適用例が増加するものと考えられる

21

Power Saving of Large-scaled Helium compressor (Masato Noguchi, Maekawa)

Abstract

About one-third of the power consumed by the linear collider is consumed by helium refrigeration equipment. For the purpose of power consumption reduction of helium refrigeration unit, it was examined the combination and optimization of the helium compressor and chemical refrigerator. Cooling the compressor suction gas by an adsorbed refrigerator with a required non-large power consumption, it was confirmed to be effective in power reduction of the entire refrigeration system. It was confirmed that heat source required to drive an adsorption chiller is to be well managed by extracting from lubricating oil system of the high-pressure-stage helium compressor. The study that was modeled on the refrigeration system of the CERN / LHC as a representative of a large refrigeration system, it was confirmed to be about 7% of the power reduction in linear collider. (This document is a report of re-validation based on what was presented at the 24th SOFT: Symposium on Fusion Technology [1].)

1. Introduction

In the linear collider, cryomodules with built-in superconducting accelerating cavities are arranged in many areas to accelerate electrons and positrons. Helium refrigeration system for cooling the cavities in cryomodule will be arranged, as shown in Figure 1, ten large 2K refrigeration station, four small 2K / 4.5K refrigeration station, and seven large refrigeration station [2]. Among the power consumed by the ILC, the power consumed by a helium refrigeration equipment is large and it is 45.81MW. The most of power is consumed in the helium compressor [2]. For this reason, it is easily leading to think about a reduction in power consumption in helium compressor in ILC. However, it can not be expected now more efficiency improvement, since the efficiency improvement has been studied in the long history of the helium refrigeration system development and the helium compressor development.

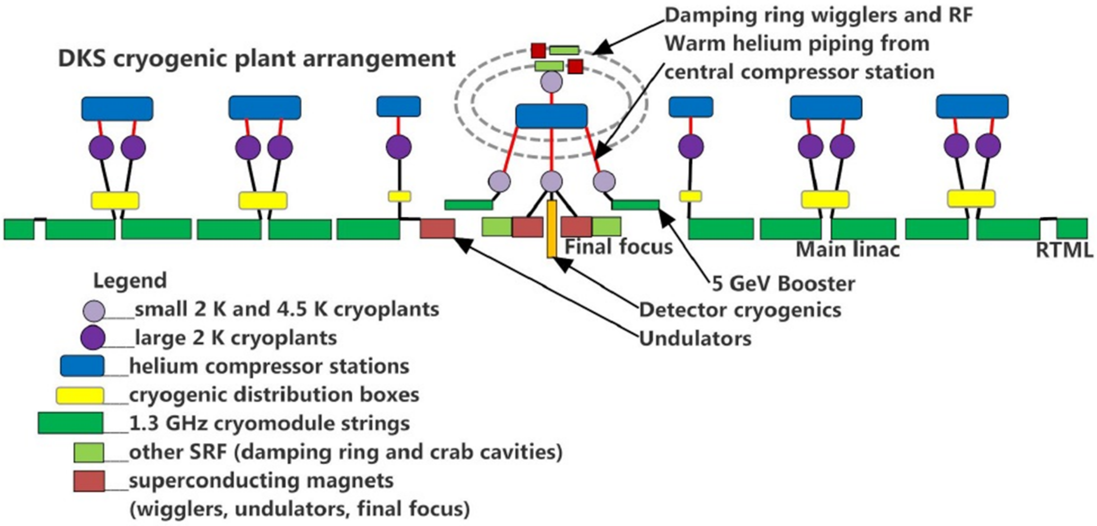


Figure 1 layout plan of ILC refrigeration unit

In an oil injection screw compressor used in the helium compressor, the suction volume capacity and the shaft power are not changed when the suction gas temperature is changed. As a result, it has been confirmed in a large helium compressor for NIFS / LHD [3,4] that the power consumption per unit weight flow rate will reduce, as the intake gas temperature become low.

On the other hand, when we install a refrigerator for the purpose of cooling the suction gas, the power consumption for the refrigerator is required, so that the benefits of power reduction of the compressor will be cancelled.

Assuming a large helium compressor be applied to the ILC, we investigated the relationship between the temperature and the heat capacity of the waste heat recovered from them. Also, we investigated what type of the chemical refrigerating system which can be driven by the waste heat, and to determine the relationship of the cooling performance and the driving waste heat.

Finally, we made to optimize the power consumption of the helium compressor and chemical refrigerator.

2. Heat balance of oil injection type screw compressor

In the development stage of helium liquefier, reciprocating helium compressor has been the standard. Later, after adopted the oil injection type screw compressor in satellite cooling system of TEVATRON at Fermilab in 1979, for large helium refrigerator system with long-term operation, oil injection type screw compressor has become a global standard.

Features of the oil injection type screw compressor is to inject a large amount of oil during the compression of the helium gas. The temperature of the lubricating oil supply is approximately 313-318K, the temperature of the discharge oil becomes comparatively low temperature (349-365K).

Considering the large helium refrigeration system, such as ILC, refrigeration systems of CERN / LHC is a good reference [5]. As a basis for comparison, we examined a similar model compressor as described above using a Japan-made compressor. The model compressor is shown in Figure 2.

The highest temperature is the discharge side of the high-pressure-stage compressor. The lubricating oil of that side has a lot of heat capacity. For heat recovery from the lubricating oil, a new heat exchanger is necessary. Recovering heat quantity from the heat exchanger is decided from the circulation amount and temperature of the lubricating oil, as shown in Figure 3.

On the other hand, the amount of heat required to add cooling of the helium gas is decided from the amount of circulation and the temperature difference between the gas. The cooling heat from the 310K is shown in Figure 4.

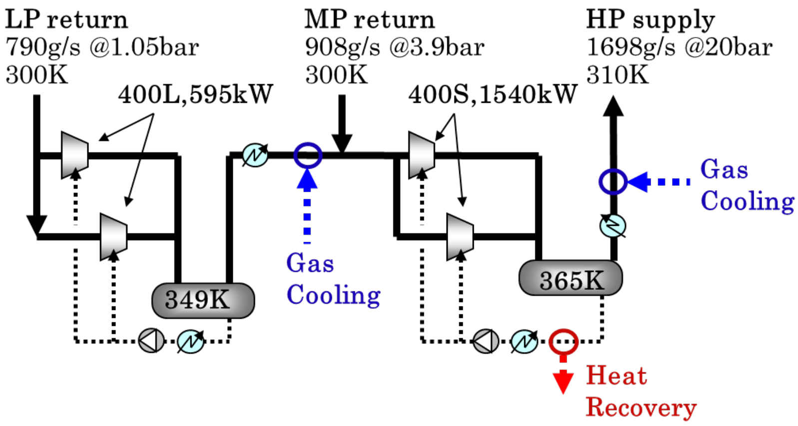
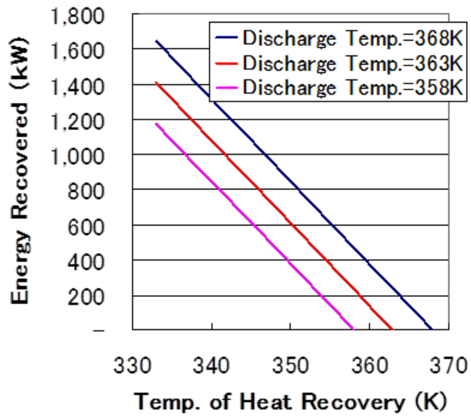


Figure 2 model compressor based on the CERN / LHC specifications.



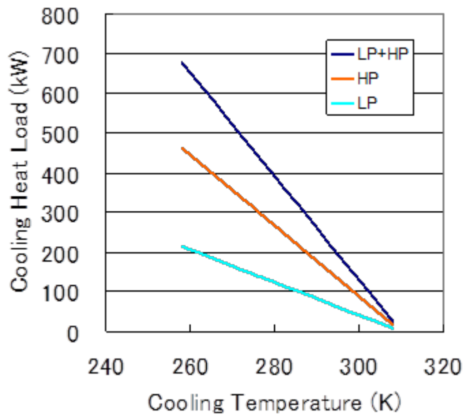


Figure 3 heat recovery temperature and the amount of recovered heat
Figure 4 required heat to add cooling of gas

With reference to Figures 3 and 4, the ratio of the cooling heat amount and the recovery amount of heat required for each heat recovery temperature, COP, can be obtained. When the discharge temperature of the high-pressure-stage compressor is set to 363K, the COP curve are shown in Figure 5. It is good if there is a chemical refrigerating machine which has a higher COP than shown in the curve.

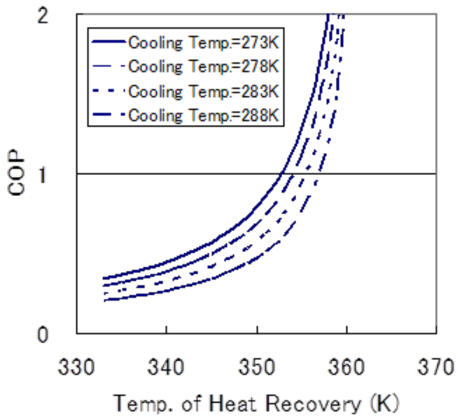


Figure 5 COP which is required in the chemical refrigerating machine

3. Chemical refrigerator characteristics

For the chemical refrigerator not consuming a lot of power to drive, there are absorption chiller and the adsorption chiller. Each of the representative structure are shown in Figure 6 and Figure 7. Also, each of the COP characteristics are shown in Figure 8.

Absorption refrigerating machine with lithium bromide solution as a refrigerant is the most common in the chemical refrigerating machine, and the COP in the drive temperature range is high. To separate the water from the dilute solution, it requires the waste heat of a relatively high temperature (≧ 360K), and seem not suitable for heat recovery applications from the helium compressor.

On the other hand, application of the adsorption chiller that can make the cold water from the lower temperature of the waste heat in recent years has been increasing. Adsorption refrigerating machine consist of two adsorbent layers, a water condenser with a built-in silica gel, and an evaporator, is operated by periodically switching the adsorption layer A / B. In the state in Figure 7, moisture adsorbing layer B is desorbed by the waste heat, and liquefied by the cooling water in the condenser. The condensed water is fed to the evaporator and evaporated in the adsorption effect of the adsorbent layer A, then it becomes low temperature.

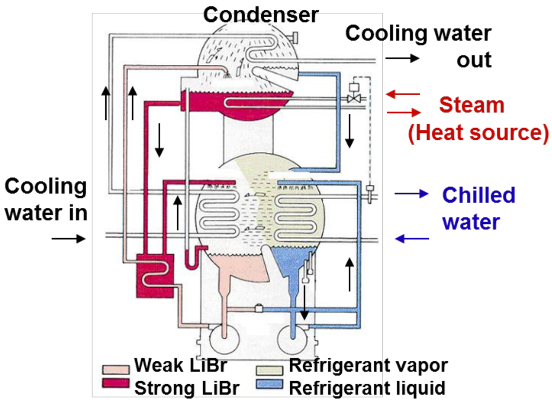


Figure 6 Absorption chiller

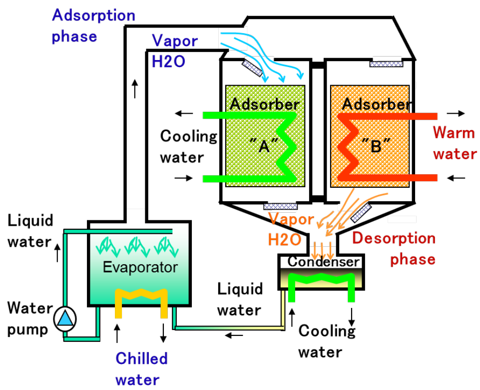
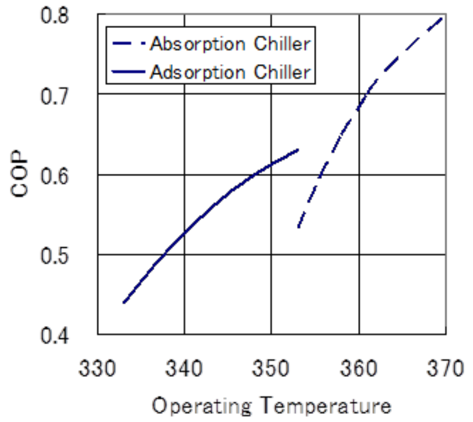


Figure 7 Adsorption chiller

An overlay to the requirements of Figure 5 with the refrigerator COP in Figure 8 is shown in Figure 9. Absorption refrigerating machine itself has high COP, however, it is not possible to exert the COP required by the system, so it is not suitable. Although the COP of the adsorption chiller is low, operating temperature is low and it has the COP required in this system.



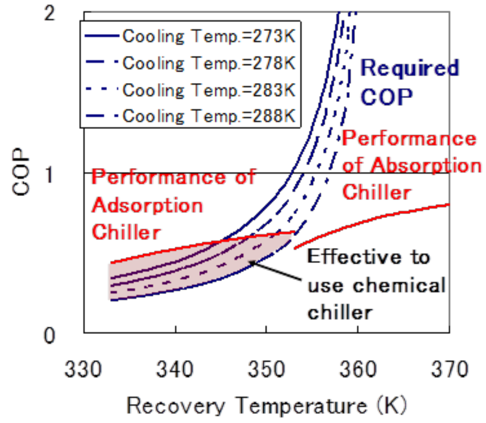


Figure 8 Chemical refrigerator refrigeration efficiency (COP)
Figure 9 Comparison of the request COP and the actual performance of the refrigerator

4. study of low temperature cycle of incorporating the adsorption refrigerator compressor suction gas

The compressor system incorporating the adsorption chiller is shown in Figure 10. By installing additional heat exchanger in the lubricating oil system of the high pressure-stage, the recovered heat is sent into the adsorption refrigerator by circulating hot water made in the heat exchanger to the adsorption refrigerator. By sending the cold water produced by the adsorption refrigerator to the newly installed heat exchanger to the gas system, the discharged gas of the low-ptessure-stage compressor and high-pressure-stage compressor is cooled.

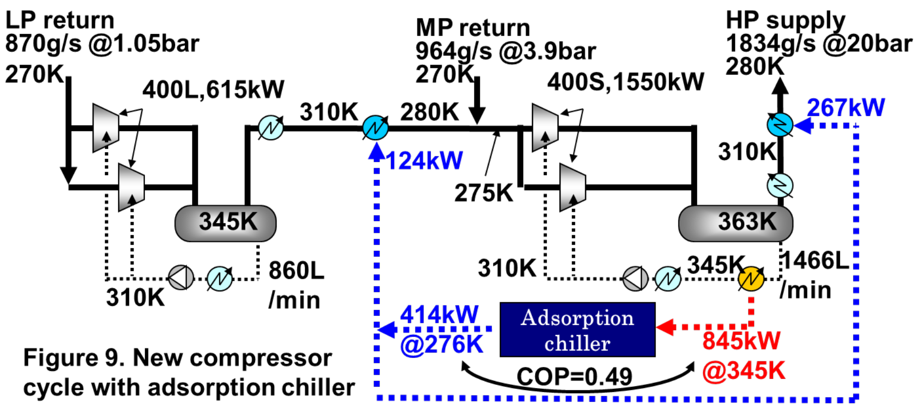


Figure 10 new compressor system incorporating the adsorption refrigerator

When the discharge temperature of the high-pressure-stage compressor is set to 363K, as shown in Figure 10, it is possible to obtain the recovered heat of 845kW with given cooling down to 345K. On the other hand, in order to cooled the helium gas of 310K to 280K by water cooling, 124kW at a low-pressure-stage, 267kW at a high-pressure-stage, total of 391kW refrigeration capacity is required. When the hot water temperature is set to 345K, and the cold water temperature is set to 276K in a heat source water of the adsorption chiller, the COP of the adsorption-type refrigerator will be 0.49, cold water of 414kW is able to produce from the input of 845kW. Accordingly, refrigeration capacity of the adsorption refrigerator has exceeded the cooling heat amount necessary for cooling of the gas, it was confirmed to be established as a system.

Incidentally, considering the helium refrigerator side, the temperature of the helium gas fed to the cold box will be down to 280K from 310K. If the temperature of the cold end of the first heat exchanger inside the cold box (here 80K) is not changed before and after the system change, and temperature of the supplying gas is changed to 280K from 310K, the high temperature portion of the heat exchanger becomes unnecessary. As a result, the temperature of the gas returns to the compressor is even down to 270K from 300K. The density of the suction gas of the compressor is increased, it is possible to make more gas flow in the same compressor. Meanwhile, the discharge pressure of the compressor is increased by adding the heat exchanger to the discharge side of the compressor, the power consumption increases.

The compressor performance under these conditions is shown in Table 1. If we use the same compressor, by making inhalation gas temperature drop, the low-pressure-stage gas flow rate (LP) / intermediate gas flow rate (MP) / high-pressure-stage gas flow rate (HP), respectively 790/908/1698 g/s will increase to 870/964/1834 g/s. On the other hand, the power consumption of the low-pressure-stage / high-pressure-stage compressor will also increase from 1190/3080 kW to 1230/3100 kW. Assuming that one can arbitrarily increase or decrease the capacity of the compressor, as a result of translation of these performance criteria of the LP800/MP880 g/s, the total power consumption of the compressor and the adsorption chiller was confirmed to be reduced to 3965kW from 4252kW, that is 7 %.

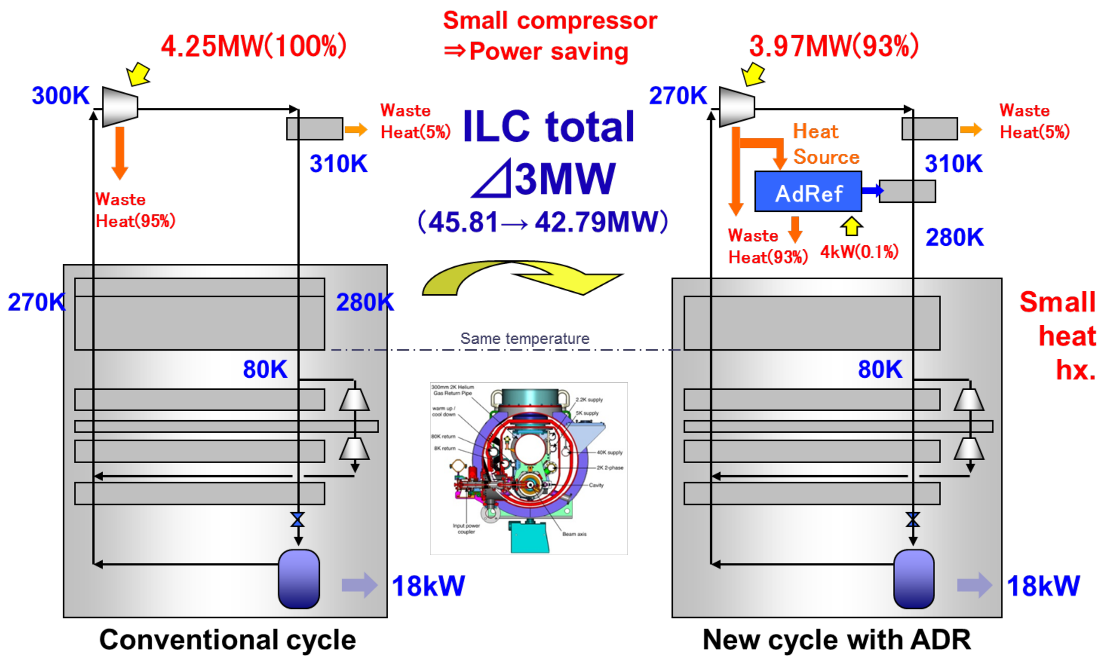


Figure 11 new helium refrigeration system incorporating the adsorption refrigerator

Table 1 power consumption comparison

			Normal Temp.	Cold Temp.
Mass Flow	LP	g/s	790	870
	MP	g/s	908	964
	HP	g/s	1,698	1,834
Shaft Power	LP-MP	kW	1,190	1,230
	MP-HP	kW	3,080	3,100
Shaft power converted to LP800/MP880 g/s condition				
	LP-MP	kW	1,205	1,131
	MP-HP	kW	3,047	2,830
	Total	kW	4,252	3,961
Power for Chiller		kW	0	4
Total Power		kW	4,252	3,965 (-7%)

5. Summary

For the purpose of power consumption reduction in large-scale helium refrigeration system in the ILC, the combination of adsorption chillers was examined.

By the study discussed above, the following results were obtained.

(1) It is possible to construct the heat cycle with the lubricating oil, as a heat source, of the compressor combined with the adsorption refrigerator.

(2) It is possible to reduce power consumption of about 7% by combining an adsorption type refrigerator.

(3) It is possible to reduce the size of the cold box, by lowering the gas temperature.

(4) The present system is self-contained, and can be operated without being affected by the load of the other lines.

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Development status of High-Tc YBCO superconducting wires (Kunihito Kikuchi, Fujikura)

1. Introduction

Superconductivity is a phenomenon in which the electrical resistance of the material is reduced to zero in the lower side of a certain temperature. Although the electrical resistance of the normal metal drops along with the temperature going down, in the superconducting material, the property of the electric resistance becomes zero below a certain temperature (the critical temperature) (Figure 1). It is not necessarily restricted only the temperature in the superconducting state, in practice, under the three critical points of the current (critical current), the temperature (critical temperature), and the magnetic field (critical magnetic field), superconducting state is emerged (Figure 2). Since superconductivity is zero electrical resistance, it is very fascinating material. From the fact that a practical application of high critical temperature superconducting material is expected in recent years, not only to the conventional superconducting equipment, but more wide range of applications are expected.

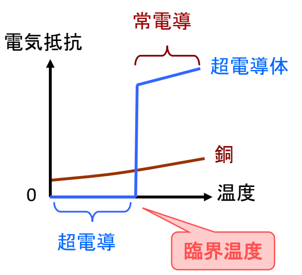

Figure 1 temperature and electrical resistance

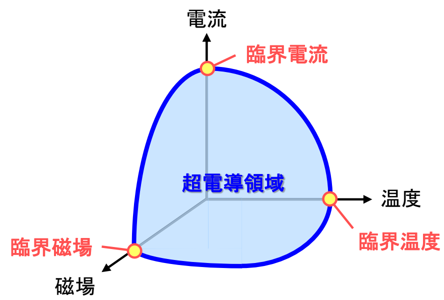

Figure 2 Three critical points of superconducting material

Superconducting was first discovered in Hg in 1911, it has been found in a variety of metal material (Figure 3). In the 1970s superconducting applications advances in particle science, metal-based superconducting material such as NbTi, Nb_3Sn, are applied to realize the wire mass production technology at an early stage. And it was established to put a practical use in superconducting applications equipment such as current MRI and NMR. These metal-based superconducting material are necessary to be cooled to cryogenic temperatures of liquid helium temperature (4.2K / -269℃). In the second half of the 1980s, the high temperature superconducting materials that exhibit superconducting state at the liquid nitrogen temperature (77.3K / -196℃) or even higher were discovered. In addition to attract much attention as the next generation of the superconducting material, many studies have been made. Unlike conventional metal-based superconducting material, the high-temperature superconducting materials are intended to be a copper oxide-based. From the commitment to the wire of the past, practical use of Bi (bismuth) system and Y (yttrium) system of high-temperature superconducting material is expected. Bi-based high-temperature superconducting wire is the first generation because it is mass-produced initially, Y-based high-temperature superconducting wire is referred to as the second-generation high-temperature superconducting wire because it is expected to mass production following the Bi-based. As described below, Fujikura has been conducting research and development of Y-based superconducting wire as a high-temperature superconductor of the second generation for practical use, and it has started the wire supply.

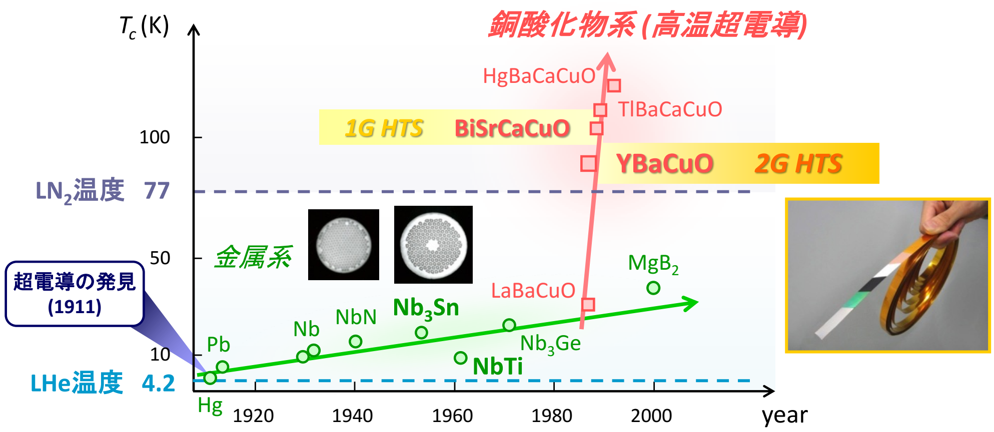

Figure 3 transition history of superconducting material

2. Superconductivity research and development of in Fujikura

Starting from the 1970s, with long history of superconductivity research and development in Fujikura, it has been done research and development of metal-based superconducting material wire and magnet, such as NbTi and Nb_3Sn. Since the discovery of high temperature superconductivity, it is quickly focus on the Y-based high-temperature superconductor, over more than 20 years since the early 1990s, it has been done research and development aimed at the wire of the Y-based high-temperature superconductor. At initial stage of development, making a short wire was the best. Since there was a boost in the wire development and application equipment development by the national project of the Ministry of Economy, Trade and Industry through the New Energy and Industrial Technology Development Organization (NEDO), wire performance increased yearly, and in 2004 Fujikura succeeded in making the world's first 100m grade wire (Figure 4) [1]. In recent years, it is reached by the level that can be supplied in the production stably of several 100m grade long wire. In 2010, Fujikura starts to supply commercial Y-based electric conductor material manufactured in-house and the wire feed for the various projects to date.

Y-based high-temperature superconducting wire has a structure obtained by laminating a thin film multi-layer (Figure 5), meanwhile, there is a technical problem that superconducting properties can not be obtained when no specific crystal orientation of the superconductive layer is aligned on a metal substrate. Fujikura solved these problems by the fundamental substrate technology that was originally developed, and has been realized the wire performance of world-class [2]. There are two of these fundamental technologies, and one is the IBAD method and the other is PLD method. First, IBAD method stands for Ion Beam Assisted Deposition, a method of forming the intermediate layer. For forming the superconducting layer having uniform crystal orientation, crystal orientation rising required to be aligned at the stage of the intermediate layer. In the IBAD method, a film-forming particles as a raw material of the intermediate layer is fed onto a metal substrate. By irradiating the assist ion beam from a particular angle at the same time, has enabled formation of a uniform intermediate layer of crystal orientation (Figure 6). Next, PLD method stands for Pulsed Laser Deposition, is a method of forming a superconducting layer. Although the PLD method itself is a general technique as a method for forming the thin film, and Fujikura employs a hot-wall type PLD method to elaborate their own ideas in. In the deposition of the superconducting layer, a deposition temperature is very important parameter. In the hot wall type PLD method, by adopting a method of enclosing the film formation area in a hot wall, the film-forming particles are succeeded in stabilizing the deposition on a substrate, and to achieve high crystallinity superconducting layer (Figure 7).

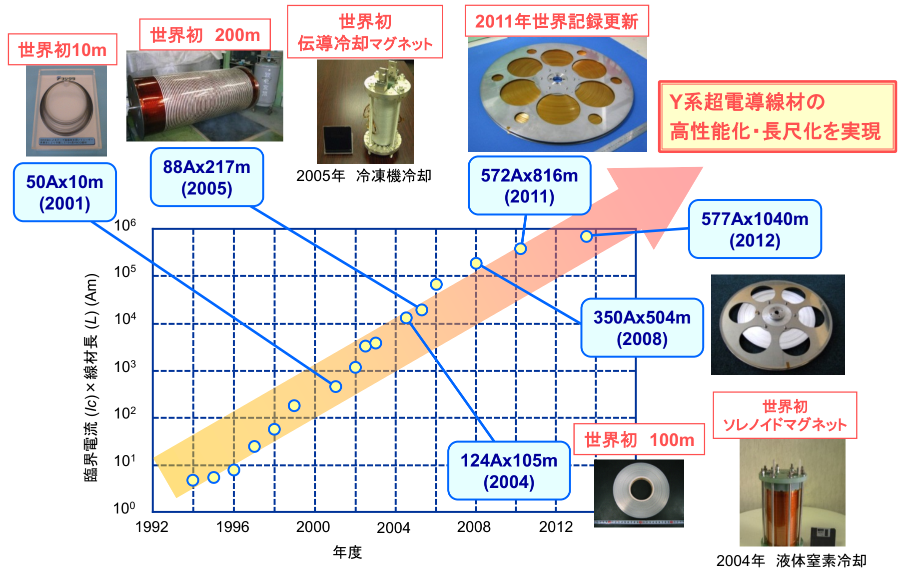

Figure 4 development of Y-based high-temperature superconducting wire in Fujikura

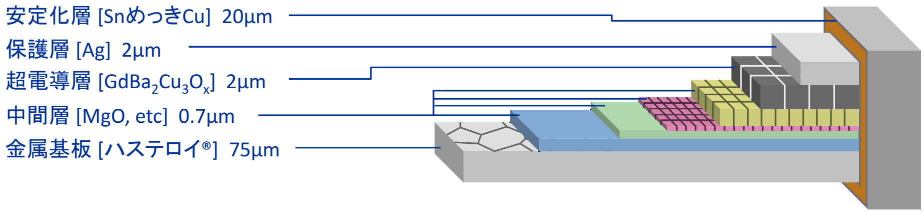

Figure 5 Fujikura Ltd. Y-based structure of the high-temperature superconducting wire (schematic diagram)

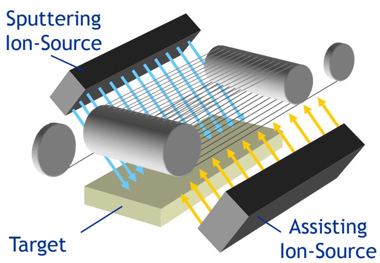

Figure 6.1 IBAD apparatus schematic

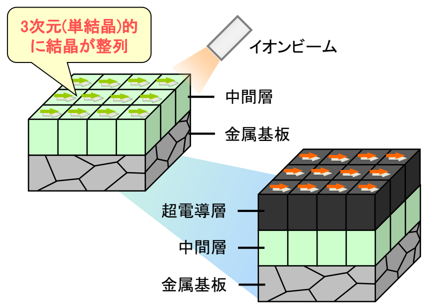

Figure 6.2 IBAD method schematic

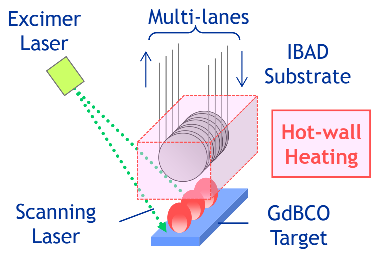

Figure 7.1 PLD device schematic

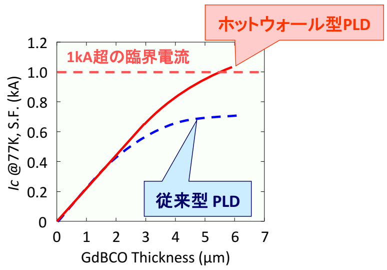

Figure 7.2 superconducting layer film thickness and the critical current in the PLD method

3. High-performance Y-based high-temperature superconducting wire

Y-based superconducting wire of Fujikura has a high critical current and a high critical current uniformity, by using a manufacturing method that was originally developed with the aforementioned feature. Critical current, in 77K, and in the self-magnetic field, is proud of the 500A / cm-wide and the world's top level of performance, has achieved a very uniform critical current distribution also in the longitudinal direction in the several 100m class of long wire (Figure 8). Although longitudinal current flow in conventional copper wire is uniform, it is difficult to get uniform current flow in the Y-based superconducting wire, because of a process of laminating a thin film, it is not easy to obtain a uniform superconducting characteristics in the longitudinal direction. From efforts for wire production over the years, Fujikura has been to improve the critical current and the longitudinal direction of uniformity, at present is being reached to a level that can be supplied to practical use [3].

When a magnetic field is applied to the superconducting material, there is a property that the critical current is reduced. Fujikura have done the evaluation of medium-critical current characteristics for the Y-based superconducting wire, including the area of up to a strong magnetic field and at low temperature, in cooperation with universities and research institutions (Figure 9) [4]. The application equipment to be used in a magnetic field as a superconducting magnet require a high critical current density in a magnetic field, it has started to consider an improvement of the critical current in a magnetic field as a future technological challenges.

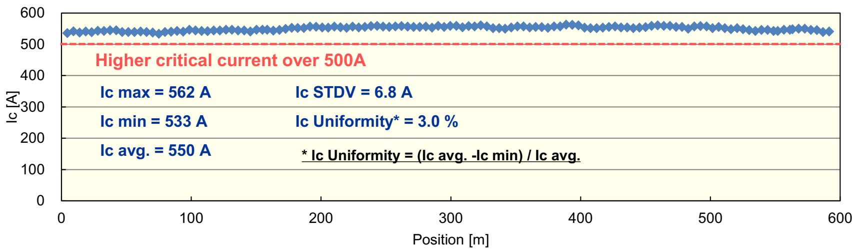

Figure 8 critical current distribution of Fujikura Ltd. Y-based high-temperature superconducting wire (reference data)

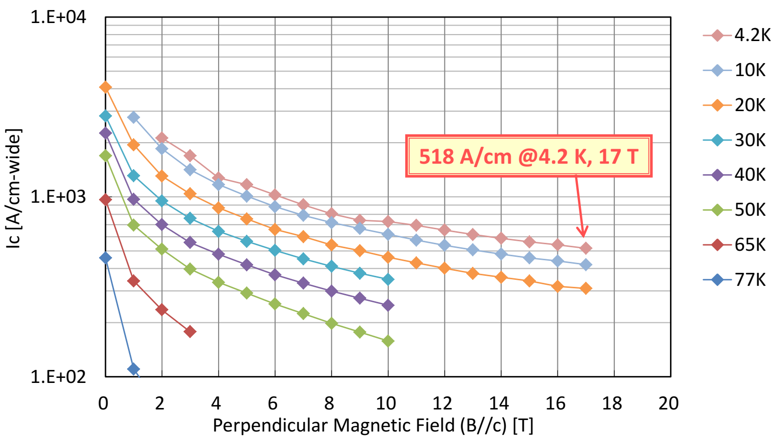

Figure 9 Fujikura Ltd. Y system in a magnetic field critical current characteristics of high-temperature superconducting wire (reference data)

※ Some of the measured data (3T ~) include the data measured by the Institute for Materials Research, Tohoku University High Field Superconducting Materials Research Center.

4. Application of Y-based high-temperature superconducting

The Y-based superconducting wire is not put to practical use yet, in recent years, long wire is able to produce stably, verification demonstration in various projects have been started. The conventional metal-based superconductor had been limited to use in a range of liquid helium temperature, the high temperature superconductor is to exhibit a critical temperature higher than the liquid nitrogen temperature, and further subject to the influence of the magnetic field for the Y-based high-temperature superconductor, it is expected commercialization in both wide area of operating temperature and magnetic field (Figure 10). Strong magnetic field magnet or the like, some of the superconducting equipment, in the future, are expected to further strong magnetic field, especially the Y-based high-temperature superconductor with less susceptible to the influence of the magnetic field, the application is expected in the strong magnetic field superconducting equipment there.

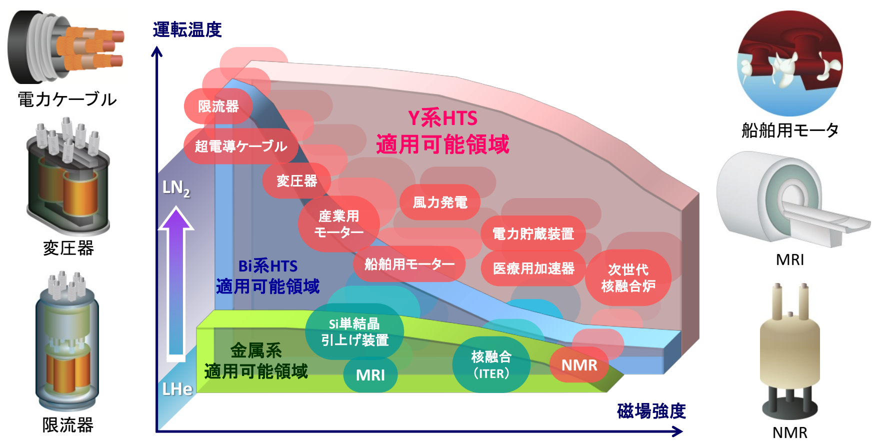

Figure 10 superconducting applications equipment

In addition to research and development of superconducting wire, Fujikura has been done a basic study of the application to the superconducting magnet and power cable. In the evaluation of the small coil is advanced for the superconducting coil, for the first time in the world, we have successfully developed a 5 T large-diameter high-temperature superconducting magnet of the room temperature bore diameter of 20cm in 2012 (Figure 11). This superconducting magnet uses a Y-based superconducting wire 7.2km manufactured in-house (the coil configuration: 300m × 24 layers), and the center magnetic field strength 5T at operating temperatures 24K, a stored energy 426kJ were achieved [5]. For superconducting power cable, by participating in the yttrium-based superconducting power equipment technology development project of the New Energy and Industrial Technology Development Organization (NEDO), we developed a 66kV / 5kA class superconducting power cable in 2013, to verify the AC loss reduction successful (Figure 12). In this project, we constructed the test line by 66kV class superconducting power cable prepared using the Y-based superconducting wire, performs 5kA energized which is largest as a power cable, and to be less 1W/m per one phase was verified. AC loss of less than 1W/m per phase at the 5kA energized, as compared with the working of the power cable (typically 154kV/600MVA class), the transmission loss of less than 1/4 in consideration of the cooling efficiency is estimated [6].

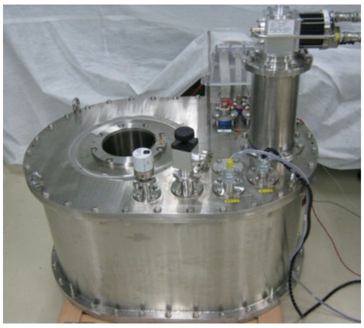

Figure 11　Y system 5 T high-temperature superconducting magnet

Figure 12　66kV/5kA class superconducting power cable

5. Summary

Fujikura have continued to research and development aimed at further improving the performance of Y-based superconducting wire. Among the project with aiming the practical use of Y-based high-temperature superconductor rises variety, Fujikura put the emphasis on the reliability of the wire itself, in addition to the performance improvement, also in wire-making that can withstand practical use, in recent years. In addition, to meet the future demand, it has also started consideration of mass production technology, there is not only in the area of traditional research and development, is also ready to enhance the production capacity as a supplier of Y-based superconducting wire. It is passed through a demonstration verification in various applications, to provide a high-performance Y-based superconducting wire which is excellent in reliability, we want to expect to be able to contribute to the realization of a low-carbon and high-efficiency energy society.

As a part of this report, "superconductivity application infrastructure technology research and development (II)," the Ministry of Economy, Trade and Industry and "yttrium-based superconducting power equipment technology development", National Institute of New Energy and Industrial Technology Development Organization (NEDO) are included for their outcome that was carried out by trustees.

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Status of High-Tc superconductor cryogenics for large volume, high efficiency and high reliability

(Naoko Nakamura, Maekawa)

1. Introduction

Adaptation of high-temperature superconducting cable to the ILC, we think useful as energy-saving technology to reduce the loss of ILC power supply. In order to introduce the current situation of high temperature superconducting cable, we report on the NEDO "high-temperature superconducting cable demonstration project", which was operated by connecting high-temperature superconducting cable to the ordinal power system, for the first time in Japan. In particular, the cooling system of high-temperature superconducting cable is an important key-technology, not only for the keeping of the superconducting state, but for the overall system efficiency and reliability improvement. In this paper, we will introduce the state of the art technology, such as developed refrigeration and cooling system in this project.

2. Outline of the NEDO "high-temperature superconducting cable demonstration project." [1], [2]

In NEDO project "high-temperature superconducting cable demonstration project", the system and the performance, operation, reliability, and maintainability of the system components were investigated, a high-temperature superconducting cable system to withstand the continuous automatic operation in the power system was build, and it was carried out to demonstrate an operation in the power system of more than one year. In parallel with the above demonstration, a large-capacity, high efficiency and reliability of high-performance refrigerator has been developed with considering the practical use of future high temperature superconducting cables. It should be noted that this project is the first project in Japan, which was operated a high-temperature superconducting cable by connecting to the power system.

Study of the impact of high temperature superconducting cable in the power system has been done by TEPCO. Study of the design, production and installation of the high-temperature superconducting cable have been done by Sumitomo Electric. Study of the design, production, and installation of the cooling system as well as development of high-performance refrigerator have been done by Maekawa Seisakusho. They were carried out respectively. The project was started from fiscal 2007. The design, manufacture, and a single verification test were done for the high-temperature superconducting cable and the cooling system. The power system interconnection test in October 2012 was carried out for continuous operation for more than one year, and in December 2013, the study was completed.

High-temperature superconducting cable that was used in this project was a three-core batch type cable with a rated 66kV, DI-BCCO of 200MVA, the length was about 240m. Considering the adaptation to the future of urban power cable laying situation in urban areas, the use of the joint, the cable bends and underground part were provided. In the Asahi substation, where the line is to step down the voltage from 154kV to 66kV, the part of the 66kV bus line was replaced to the high-temperature superconducting cable. Photos of the high-temperature superconducting cable used in this project is shown in Figure 1.

Figure 1 photo of high-temperature superconducting cable

3. cooling system used in the demonstration and its challenges [3]

The cooling system used in this project is the close circulation device. It is composed of refrigerators, circulation pump, and a reservoir tank. The sub cooled liquid nitrogen refrigerant (hereinafter, LN2) were used. LN2 that are sent by the circulation pump performs circulation cooling of the high temperature superconducting cable after cooled in the refrigerator. Flow of the cooling system and the installation situation are shown in Figure 2 and Figure 3.

Selection was made for a refrigerator type by the results to date, and it was also decided the number of refrigerator by the heat loss of the high-temperature superconducting cable system. In the cooling system, six of 1kW@77K Stirling refrigerator were used, and made them in three parallel × 2 units, considering pressure loss in the heat exchanger, the temperature controllability, and backup during the fault. Two centrifugal circulation pump were placed in parallel. In addition, one refrigerator one and one circulation pump is in the spare, they were automatically activating in the event of a fault. The volume of the reservoir tank was 1000L, considering of the volume change due to temperature change of LN2 in the high-temperature superconducting cable. Furthermore, it is necessary to maintain the pressure more than 0.2 MPaG in LN2 system for keeping electrical insulation of high-temperature superconducting cable, it was installed 3 types of pressure control device including the spare unit into the reservoir tank.

As described above, a circulation cooling of high-temperature superconducting cable using LN2 of sub-cooled state was performed in this project, but the operating temperature of LN2 was controlled to 69±1K (standard value) at the inlet temperature of the high temperature superconducting cable, considering the critical temperature of the superconducting material, LN2 temperature rise at the time of trouble such as a short circuit, and temperature margin. Specifically, the operation number control was performed in order to control the temperature by matching the variation in heat loss of the high-temperature superconducting cable between seasons and in a day. Control of operation number of the refrigerator is a commonly used method, even with cold water chiller refrigerator for pipe-tunnel cooling of underground cables, maintenance concept on the power plants are considered.

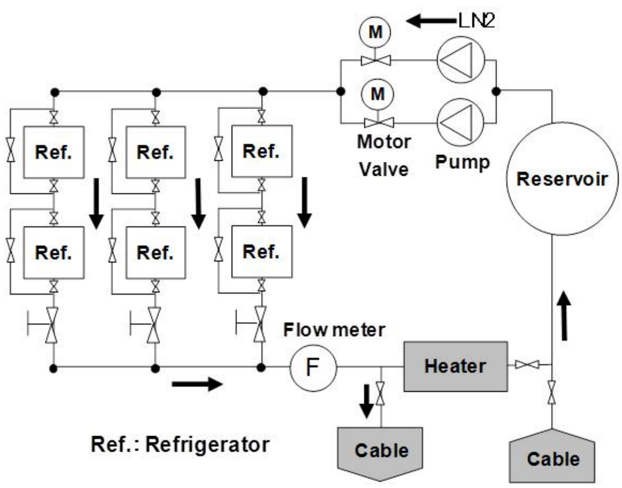

Figure 2 flow of high-temperature superconducting cable cooling system

Figure 3 photos of the high-temperature superconducting cable cooling system

Current through the high-temperature superconducting cable in the demonstration, temperature of LN2, pressure, and flow rate are shown in Figure 4. The demonstration test, which was lasted 1 year or more, was completed successfully without any big trouble. During this time, not stopping the circulation cooling may be considered as a major achievement. In addition, by the temperature control of the refrigerator, by the pressure control in the reservoir tank, sub cooled state of LN2 was kept, and even possible to achieve a stable long-term circulation cooling. Furthermore, even it was performed several times of the refrigerator replacement work during demonstration, LN2 circulation state was stable, no obstruction of LN2 circulation by ice or so, maintaining the LN2 circulation operation, so, it was able to establish a working techniques to replace disconnected the equipment only individually.

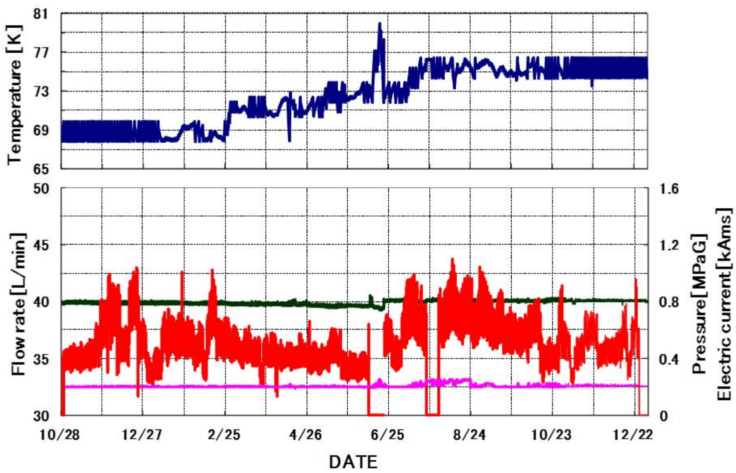

Figure 4 test results of the demonstration

While operation of high-temperature superconducting cable has verified without problems in the power system, however, for practical use, it has become clear that there are a number of challenges. Examples of the resulting problems are described below.

In this cooling system, the six refrigerator were connected with vacuum insulation piping, and further, the bypass line for the refrigerators for maintenance were installed. Therefore, increasing the number of valves of vacuum insulation pipes and bypass, their loss became comparable to the refrigerating capacity of one refrigerator in the cooling system. In order to increase the overall efficiency of the high-temperature superconducting cable system, improvement of the refrigerator efficiency, reducing the loss of the high-temperature superconducting cable, and reducing heat losses in the cooling system, are required. large capacity of the refrigerator which has reducing the effect of heat loss of the cooling system, is thought to contribute to the high efficiency of the entire superconducting cable system.

In this project, the power consumption of the cooling system required to cool the high-temperature superconducting cable is defined as the cooling system COP. In the cooling system used for the verification test, the efficiency has been unquestioned, however, in order to give the operational benefits of future high-temperature superconducting cable, it has to be a COP of 0.1. However, as the results of this verification test, the cooling system COP was approximately 0.04.

Lowering of the refrigerating capacity of the refrigerator started after the start of three months during verification test, sequential performance degradation was seen in the six refrigerator. In order to maintain the refrigerating capacity, 1-2 times of evacuation and the overhaul of the refrigerator by manufacturers were performed monthly. When we use it in a power system, the reliability of the cooling system and longer maintenance intervals of the device are also important. Therefore, it is necessary to develop a refrigerator of long maintenance intervals.

Considering above results, a large capacity, high efficiency, high reliability of the Brayton refrigerator has been developed and introduced in the next section.

4. Development of high-performance refrigerator [4]

In terms of the aim of practical application of high-temperature superconducting cable, since a large-capacity, high efficiency and high reliability refrigerator was essential, from February 2011, in parallel with the demonstration test at Asahi substation, development of a high performance refrigerator was performed in this project. Considering the loss of high-temperature superconducting cable during practical application, required single refrigerator capacity was assumed as 5 ~ 20kW, this time target refrigerator capacity was set to 5kW which was 5-6 times the capacity of the current Stirling refrigerator. Furthermore, the loss of the cable system is required to be reduced by 50% over than ordinal cables, in order to achieve this, the goal COP of the cooling system was 0.1. Also, considering the practical use, maintenance intervals of the refrigerator is also an important evaluation items, and 30,000 hours, which were general industrial refrigerator equivalent, were targeted in this project.

To achieve the development goals above, reversed Brayton cycle was adopted in the refrigerating cycle. Reverse Brayton cycle is a refrigeration cycle consisting of insulating process and isobaric process, it is a gas cycle, but, it is the heat pump radiating heat out of the system. The basic system flow and photographs of Brayton refrigerator that was developed in this project are shown in Figure 5 and Figure 6. In adiabatic compression process, considering the refrigerator efficiently become better for plus work from the outside isothermally, and considering the proper pressure ratio of the compressor, the refrigerator employs the three-stage compression. In addition, the turbo type compressor and expander were adopted in order to maximize the characteristics of the reverse Brayton cycle. In addition, in order to be the cooling system COP to 0.1, the design value of the adiabatic efficiency of the turbo compressor-expander was set to 0.8.

Considering refrigerator efficiency, the shape of the rotor blades, a motor specification, and the economical efficiency, first-stage and second-stage turbo compressor, and, the third-stage turbo compressor and turbo expander, are integrated. By integration of the turbo compressor and turbo expander of the third stage, power generated by the expander is consumed for a part of the power for driving the third-stage compressor, which contributes to the efficiency improvement of the refrigerator. The refrigerant of the refrigerator, the helium gas and neon gas has a potential, since it is required to be a low boiling point. In turbo machine, as the molecular weight of the working fluid is small, it become high rotation and tend to be compact, because much high difficulty of the manufacturing as to be compact as described above, we adopt the neon gas refrigerant in this development. Since the rotational speed of the rotary machine in the case of using the neon gas refrigerant becomes 40,000 ~ 70,000rpm high speed rotation, the bearings were used non-contact oil-free bearings. It realizes the increase of maintenance intervals by using non-contact oil-free bearings, and increased the reliability of the refrigerator. This horizontal type compressor with the pressure sealed structure placed the rotor blades in both ends around a built-in motor. Structure of three-stage compressor and the expander were also similar, but it had the vertical structure for disposing the expander side in the cold box.

This refrigerator consists of, a turbo compressor and an expander, first-stage and second-stage integrated turbo compressor, expander-integrated third-stage turbo compressor, cold recuperator heat exchanger for utilizing the cold heat generated in the expander, LN2 heat exchanger that performs heat exchange between LN2 and neon, and the water heat exchanger for dissipating the heat of compression to the outside air in the cooling water. The cold recuperator heat exchanger and LN2 heat exchanger were adopted aluminum plate-fin proven helium liquefaction refrigerator. Turbo expander, cold recuperator and LN2 heat exchanger were installed in the cold box, other devices were installed as a compressor unit on a single frame. Considering the ceiling height of the cooling system building of Asahi substation, it was making a structure for drawing the body of the vacuum chamber while leaving the top plate of the cold box down, and making easy maintenance of the equipment installed in the cold box in the cooling system building.

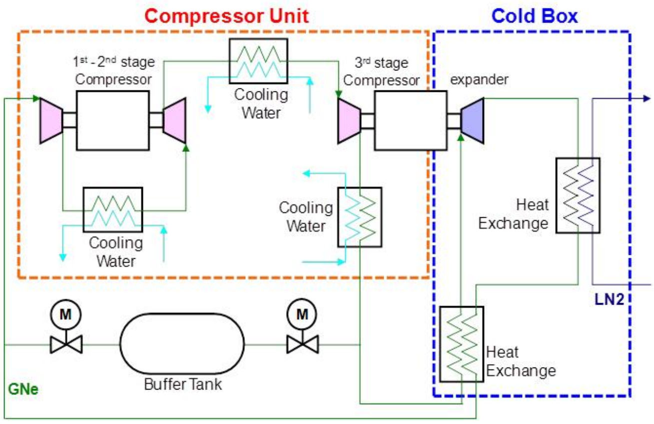

Figure 5 Brayton refrigerator flow

Figure 6 Brayton refrigerator photo

The results of performance test, the refrigerating capacity of the refrigerator was 5.8kW@77K, and COP was 0.1@77 K, then it was a certain degree of success. Therefore, as a basement of the structure of the circulation system, which was introduced in Chapter 3, we have developed a cooling system equipped with this refrigerator. At the factory testing, the performance of the cooling system, the controllability, and the operability and so on, have been transferred to the Asahi substation after confirming that there is no problem. Currently, in preparation for the long-term continuous operation in a power system on which we plan to start from summer 2015, the final confirmation of the cooling system has been performing.

5. Summary

Adaptation of high-temperature superconducting cable to the ILC, we think useful as energy-saving technology to reduce the loss at the time of ILC power supply. In this paper, we introduce the state of the art of refrigeration and cooling systems that have been developed by NEDO "high-temperature superconducting cable demonstration project" of high-temperature superconducting cable that is attracting attention as the future of energy-saving technology.

Demonstration that lasted more than one year, was successfully ended without any big trouble, and it made a big success. However, assuming a future superconducting cable commercialization, it also became clear that there are problems in the capacity of the refrigerator, the efficiency, and the reliability. Therefore, development of large capacity, high efficiency, high reliability of the refrigerator was carried out.

The refrigerator using turbo compressor and the expander, aimed large capacity, high efficiency, and high reliability, by reverse Brayton cycle, multi-stage of the compressor, and the adoption of magnetic bearings. The results of performance test, refrigeration capacity and COP were both able to accommodate certain results. We performed relocation to the Asahi substation. We are currently preparing for the demonstration test connected to the power system in summer 2015.

Reference

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Energy saving and Cost Reduction in High-Voltage Substation and Distribution System for Green-ILC (Tadashi Fujinawa, Riken)

1. Introduction

Accelerators are mainly operated nonstop for a long time and require a large amount of electricity. From this point of view, an AC power supply system must be highly reliable, economical, and efficient.

The author proposes a new high-voltage (HV) substation and distribution system using Green ILC, which can achieve energy savings and cost reduction based on the RI beam factory (RIBF) experience of the RIKEN Nishina Center. Using this proposed substation and distribution system, the construction cost will be less than half of that of the technical design review (TDR), and the amount of energy savings will be 9,218MWh per year.

2. HV substation and distribution system of TDR

The plan for the transmission and distribution of ILC using TDR was accepted by both Kyusyu Electric Power Corporation and Tohoku Electric Power Corporation and is excepted to supply 275kV, according to the report of the Large-Project Division of AAA two years ago (2013).

Fig. 1 shows the general plan. Fig. 2 shows the main substation single-line diagram (SLD). Fig. 3 shows the SLD of a 66kV/6.6kV [HV/medium voltage: (HV/MV)] substation.

This plan was designed by an engineering consultant company requested by the High Energy Accelerator Research Organization (KEK), which is simply an expansion of KEK and the J-Pack facility.

Fig. 4 shows a photograph of the RIKEN Nishina Center HV/MV substation for reference.

The author expresses some doubts on the plan and will present my comments and explanation of each item.

1) Receiving voltage

TDR plans 275kV as the receiving voltage, but Kyusyu Electric Power

Corporation does not have a 275-kV system. It uses 220kV instead of 275kV. The power receiving voltage in the Kyusyu area is 220kV, and no other voltage option is available.

In the Tohoku area, the supply voltage is 154kV for a 200-MW load. In addition, the JFE Steel Corporation Chiba Works and Nippon Steel & Sumitomo Metal, both in Chiba Prefecture, and the Kashima Kita (north) Industrial area where Mitsubishi Chemical Corporation has its flagship

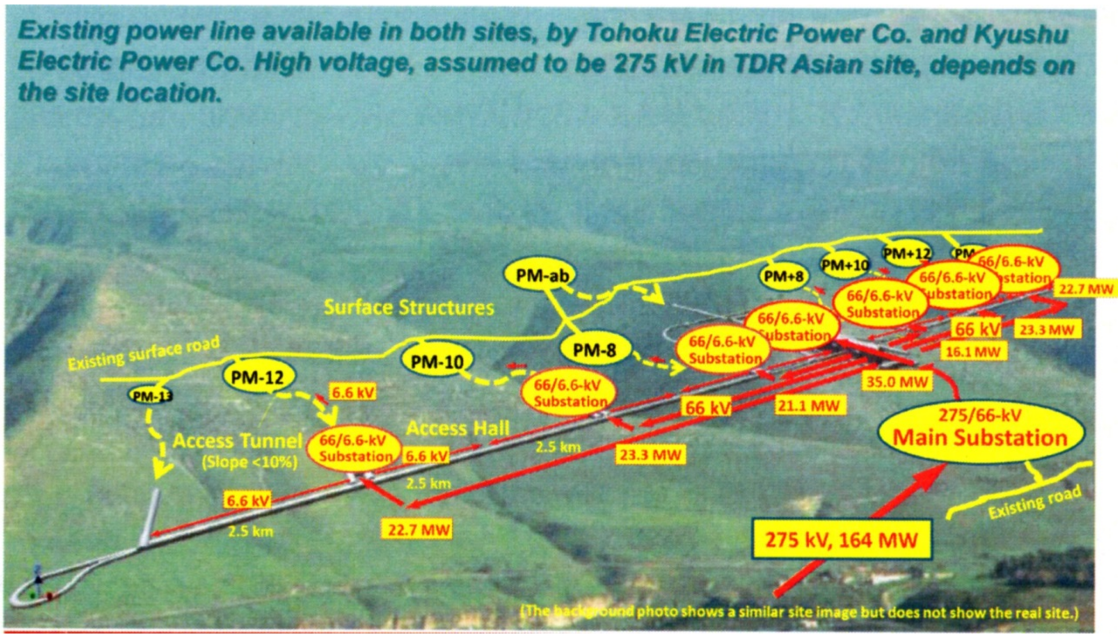


Fig.1 This drawing shows that the 164-MW power will be received at 275kV/66kV main substation from the utility company, and power is distributed to the seven 66kV/6.6kV HV/MV substations using 66kV underground cables. The received power at each HV/MV substation is less than 30MVA.

project receives 154kV from Tokyo Electric Power Corporation. The Kashima Minami (south) industrial area uses 66-kV distribution systems. Kashima area is in the Ibaraki Prefecture. The only example where a 275-kV supply exists is in Tohoku-epco for the East Japan Railway.

2) Economic performance

The 275 kV-transmission lines are directly connected to large power stations and create a basic power grid. However, in Japan, the manufacturers of 275-kV equipment are only Hitachi, Toshiba, and Mitsubishi Electric, and the equipment is very expensive compared with that in the 154-kV system. In addition, an expensive microwave tower and its communication systems are required in the 275-kV substation in the Tohoku-epco area. We have to note that a 275-kV substation requires a first-class licensed engineer (which is currently rare after the Fukushima Daiichi Nuclear Power Station disaster), whereas a second-class engineer is required for a 154-kV substation.

The Large-Project Division of AAA has estimated an HV substation system. Under the same voltage, a 60-Hz transformer will cost lesser than a 50-Hz transformer because the 60-Hz transformer is smaller than a 50-Hz one. However, in a 220-kV versus 154-kV system, the 50-Hz transformer has an advantage in terms of cost.

The TDR plan has twice the capacity and spare power; thus, we must consider the economic aspect. With this design, not only the construction costs but also the operation costs increase. The large number of transformers causes more iron loss (no-load loss), and the series connection of the 275-kV (154kV/66kV and 66kV/6.6kV) system creates large losses from both hysteresis and Joule heating losses.

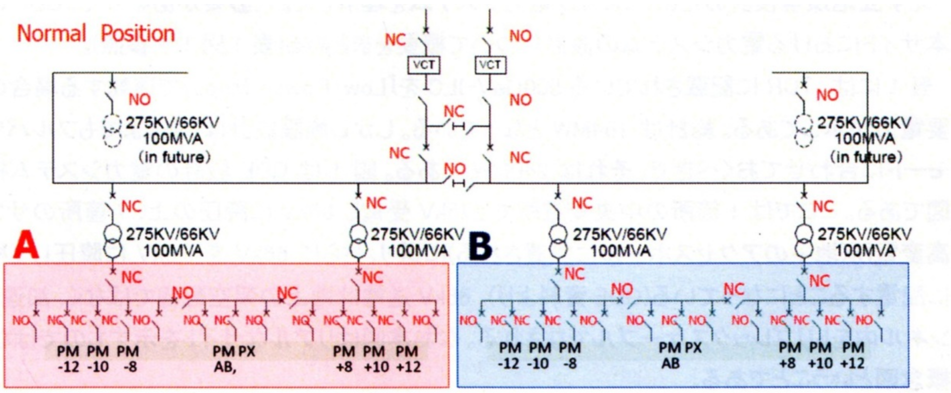


Fig. 2 The 275-kV/66-kV main substation is heavily-protected. NC means normal close (ON), NO is normally open (OFF). This SLD shows four times the number of 100-MVA transformers compared with a load of 164 MW as shown in Fig. 1. This plan also shows two extra gas circuit breakers (GCB). The areas colored pink and blue are layout of the 66-kV vacuum circuit breakers (VCBs). The feeders from A and B are connected to the 66-kV/6.6-kV HV/MV substations with the 66-kV underground XLPE/PVC cables.

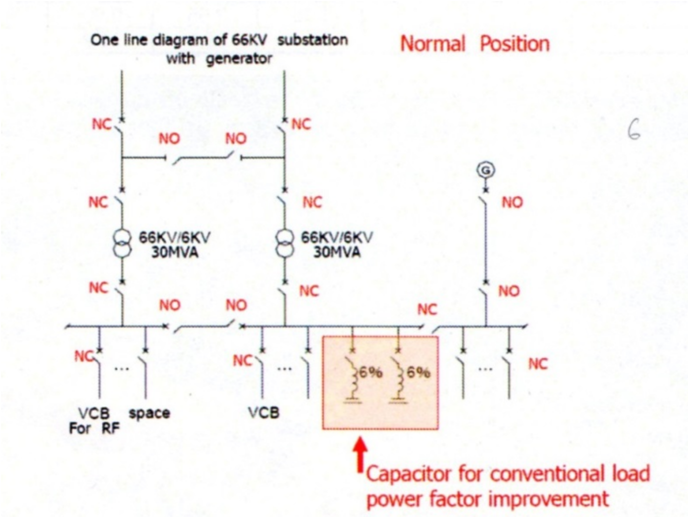


Fig. 3 SLD of the 66-kV/6.6-kV substation. The seven HV/MV substations are arranged. Each substation has loads from 10 to 15 MW, but the transformer capacity is 60 MVA. This drawing shows an emergency 6.6-kV generator and capacitors for conventional power factor improvement, but the capacities are unknown.

3) Reliability

The TDR has two lines for power reception: one is for normal use, and the one is for spare. However, the two lines are installed in one tower. From our experience, a jet plane simultaneously severed two lines due to engine trouble, and a crane ship severed two lines above a river. Both created long-time power outages. The two lines are connected to the same power source (substation). Thus, in the event of substation trouble, both lines will be de-energized.

A two- line power receiving system can be considered useful only for scheduled power outages, although it is costly. The RIKEN Wako campus employs the same system yet still experiences sudden power outages.

The most serious concern is the series connection of the HV/HV and HV/MV transformers. If one of them is damaged, the system will not work. Therefore, the two sets of equipment have a two times probability of failure compared with one set.

Fig. 4 RIBF substation. The front is a 66-kV gas-insulated substation with a VCB. The back row shows a transformer with a capacity of 25/30 MVA and the 6.6-kV metal-clad switch gears behind.

3. Proposed plan for Green ILC

Fig. 5 shows the proposed plan of the HV substation and distribution system made by the author.

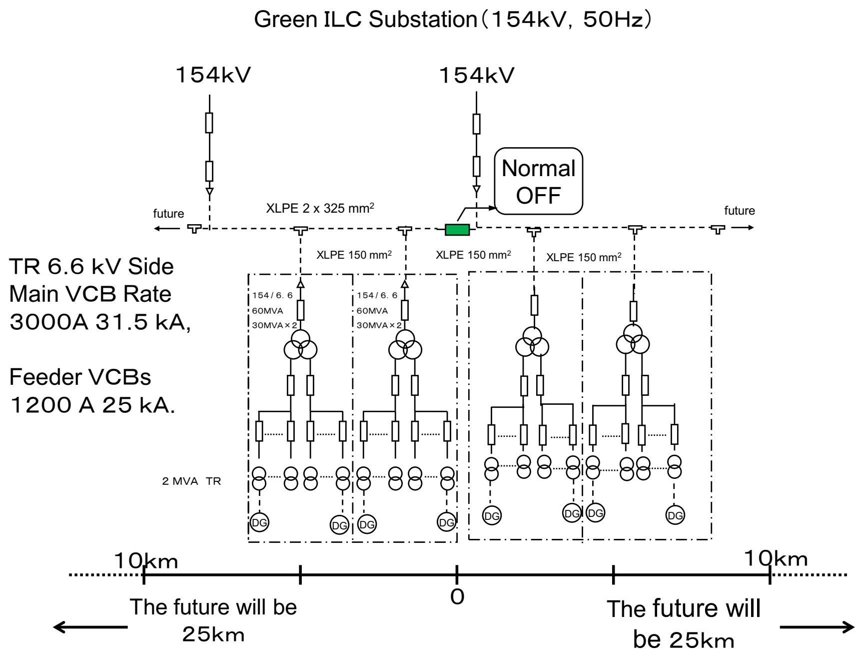


Fig. 5 SLD of the energy-saving system. The drawing corresponds to those shown in Figs. 3 and 4. Green ILC will arrange two switchyards and receive power from different power utility sources such as the A and B substations. The two lines are energized at all times and supply power via four 60-MVA HV/MV transformers. In case one line is de-energized, the green normally off GCB will switch on immediately and supply power within 6 Hz (12 ms). With this almost uninterruptible power supply system, we can operate cryogenic refrigerators, vacuum systems, and other important loads without interruption.

First, the voltage should be 154kV from the Tohoku-epco area, which was recommended by the Large-Project Division of AAA. The 275-kV system cost is very high compared with the 154-kV. In addition, the Tohoku-epco has no plan of supplying 275kV at all.

Green ILC has two switchyards and receives power from different power sources of Tohoku-epco. In case the total required power is 200MW, both substations will supply 100MW each. One normally off GCB is installed in between. If one side experiences a sudden power failure, the high-speed under-voltage relay automatically orders the GCB to "switch on," as indicated by the green color. From this action, we can operate cryogenic and other systems without interruption. The main distribution cable size is two 325mm^2, and the feeder cables are 150mm^2. The main cable capacity is 240MVA, and the allowable power in each feeder is more than 60MVA. This type of different power supply system can be used in government prefecture and other essential loads.

The required transformer sets will only be four 154kV/6.6kV (HV/MV) 60MVA, and they will be distributed at the same interval. From this setup, this system does not require 154-kV/66-kV HV/HV transformers, and savings in terms of losses from the said HV/HV transformers can be realized. The 14 transformers in the TDR will be converted to only four transformers, thus a significant savings in terms of lesser number of circuit breakers, disconnect switches, bus bars, and other equipment will be realized. In addition, fewer parts mean fewer troubles, which increase reliability.

The reason for the HV/MV is that it has two windings of 6.6kV 30MVA for the MV circuit breaker maximum capacity of 3,000A, which makes the MV side achieve a maximum capacity of 30 MVA. I believe that TDR chooses 66kV/6.6kV for the 30MVA transformers.

The construction cost of the proposed system is approximately half that of the TDR system owing to its fewer equipment and simple structure.

The performance of both systems can be quantitatively calculated. The conditions are as follows:

The power requirement of Green ILC is 200MW. The amount of CO_2 emission from Tohoku-epco is 0.591kg/kWh in 2014. The electrical cost is ¥12/kWh. The operation time of Green ILC will be 7,000h/year. Fig. 6 shows the transformer efficiency: one 100 MVA, seven 30MVA, and eight 60MVA.

TDR system: (4 × 100MVA + 14 × 30MVA)

1) 100MVA at 50% load, η= 99.49 at 50MW: 1 - 0.9949 = 0.0051; 50MW × 0.0051 = 255kW. 4 × 255 = 1.02MW (total). The iron loss is 125kW for a total of 4 × 125kW = 500kW.
2) 30MVA at 47.6% load, η= 99.545% at 14.3MW: 1 - 0.9945 = 0.0055; 14.3 MW × 0.0055 = 79kW. 14 × 79 = 1.1 1MW. The iron loss is 22kW for a total of 14 × 22kW = 308kW.
3) Total loss

   During operation: 1.02MW + 1.11MW = 2.23MW

   During maintenance: 500kW + 308kW = 808kW (1,760h/ year)

Green ILC system: (154kV/6.6kV, 60MVA × 4)

Load factor is 83% of the 60MVA, which is 50MW. η= 99.40%: 1 - 0.994 = 0.006;

4 × 0.006 × 50MW = 1.2MW (almost half). The total iron loss is 4 × 50kW = 200kW.

The comparison of both systems is presented as follows:

Energy loss during operation time: 2.23MW – 1.2MW = 1.03MW (7,210MW/year)

During maintenance: 808kW – 200kW = 608kW (1,070MWh/year at 1,760h/year)

Total: 7,210MWh/year + 1,070MWh/year = 8,280MWh/year

Electrical cost of transformer loss:

During operation: 1,030KW × 7,000h/year × ¥12/kW·h = ¥86,520,000.00/year

During maintenance: 608kW × (8,760 - 7,000) × ¥12/kW·h = ¥12,840,960.00/year

Total amount: ¥86,520,000.00/year + ¥12,840,960.00/year = ¥99,360,960.00/year

CO_2 emission

During operation: 1,030kW × 7,000h/year × 0.591kg/kW·h = 4,261,110kg/year

During maintenance: 608kW × (8,760 - 7,000)h/year × 0.591kg/kW·h = 632,417 kg/year

Total: 4,261,110kg/year + 632,417kg/year = 4,893,527kg/year = 4,894ton/year.

Cable loss

The cable size capacity is same as the capacity of the transformers. The calculations were made by PAT No. 263544. The other conditions are same as those in the transformer loss calculations.

TDR system

1. 66kV XLPE/PVC Cable 150mm^2 for 14 feeders

2. Each cable length is as follows : 4 × 11.65km, 4 × 7.7km, 4 × 4.1km, and 2 × 0.4km
3. The current is 125A (14.3-MW base); the conductor temperature is 49.1°C.
4. The cable losses are 25.2kW for 11.65km, 16.6kW for 7.7km, 9.0kW for 4.1km, and 0.9kW for 0.4km.
5. The total loss is 205kW or 1,435,000kW·h/year; the CO_2 emission is 848tons per year.

Green ILC system

1. Main cable: 154kV XLPE/PVC 2 × 325mm^2 (51.4°C at normal current of 450A and maximum current of 900A)
2. Transformer feeder cable : 154kV XLPE/PVC 150mm^2, 225A at 60MVA and 200A at 50MVA at 69.5°C.
3. Each cable length is as follows: for the main cable—2 × 6.2km and 2 × 3.1km; for the feeder cable—0.4km.
4. Cable losses: main cable —for 2 × 6.2km, 375A at 100MW is 56kW and for 2 × 3.1km, 188A at 50MW is 6.9kW. The total loss for the four cables in the feeder is 8.1kW.
5. The total cable loss is 71kW. The electrical loss is 497,000kW/year. The CO_2 emission is 294tons.

Difference between the TDR and Green ILC:

1. Cable portion: 1,435,000kW·h/year - 497,000kW/year = 938,000kW/year. (¥11,256,000.00)
2. Grand total: 9,218MWh/year, ¥110,616,960.00/year, and 5,448tons of CO_2 per year. We can consider this as monergy.

2015年2月5日
三菱電機株式会社
系統変電システム製作所

100MVA油入変圧器の効率曲線

Efficiency Curve

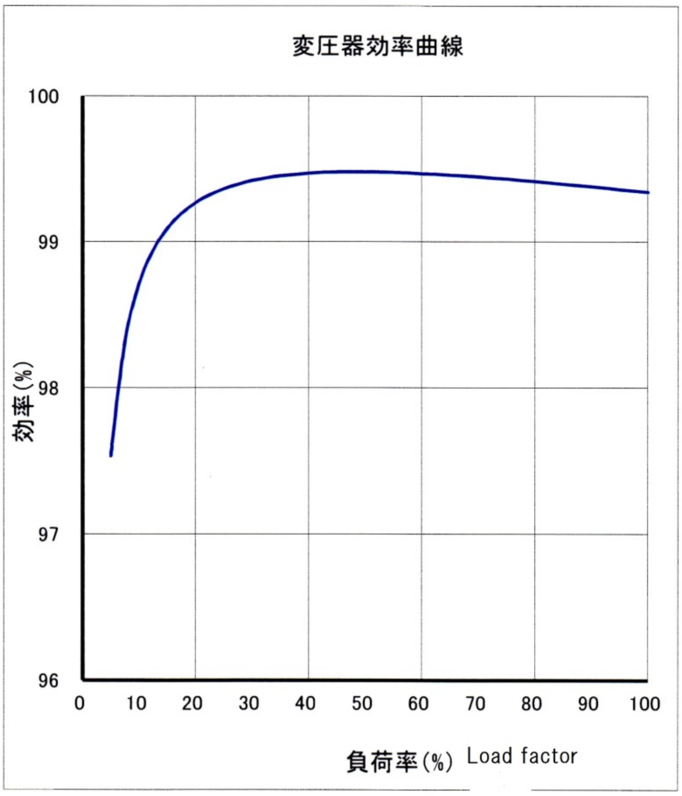
1. 変圧器仕様

特別三相, 50Hz, 導油自冷式, 負荷時タップ切換器付, %Z＝11%, 内鉄形, 騒音値65dB(防音壁付)
一次側: F168～R154～F140kV, 星形
二次側: 66kV, 星形
安定巻線(三角形)付

2. 損失

無負荷損失(鉄損)　125 kW　Iron Loss
負荷損失(銅損)　530 kW　Copper Loss
補機損失は含みません。
※損失は参考値であり, 変圧器の仕様変更, 詳細設計により変わる可能性があります。

3. 変圧器の効率曲線



変圧器効率	
Load (%)	効率(%)
5	97.54
10	98.71
15	99.10
20	99.27
25	99.37
30	99.43
35	99.46
40	99.48
45	99.49
50	99.49
55	99.48
60	99.48
65	99.47
70	99.45
75	99.44
80	99.42
85	99.41
90	99.39
95	99.37
100	99.35

SDT-K・8734
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Fig. 6 TDR main transformer efficiency curve. 154kV/66kV, 100MVA, 99.35% at rated capacity.

Efficiency Curve
30MVA油入変圧器の効率曲線

2015年2月5日
三菱電機株式会社
系統変電システム製作所

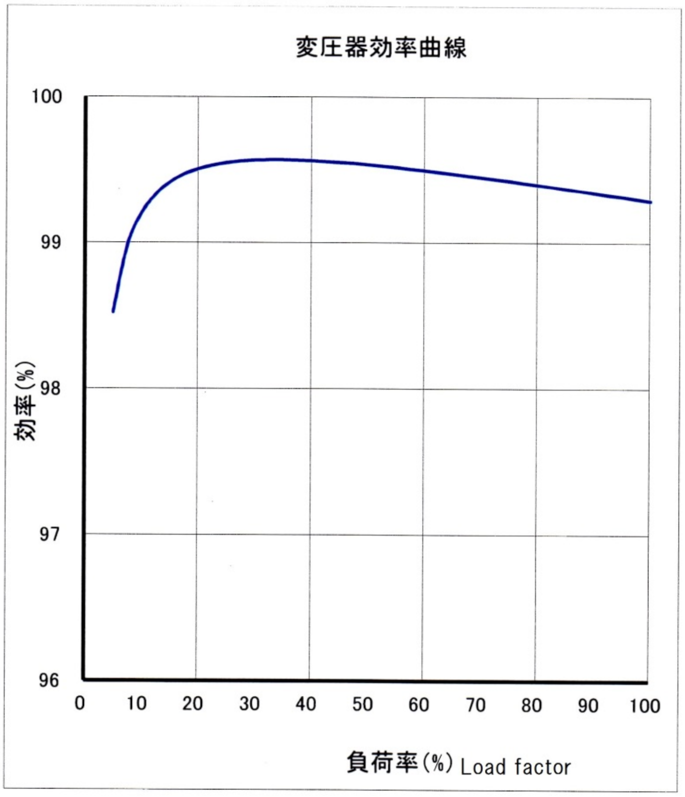
1. 変圧器仕様

三相, 50Hz, 油入自冷式, 負荷時タップ切換器付, %Z＝15%, 内鉄形, 騒音値65dB
一次側: F72～R64.5～F57kV, 星形
二次側: 6.9kV, 星形
安定巻線(三角形)付

2. 損失

無負荷損失(鉄損)　22 kW Iron loss
負荷損失(銅損)　190 kW Copper loss
※損失は参考値であり, 変圧器の仕様変更, 詳細設計により変わる可能性があります。

3. 変圧器の効率曲線



変圧器効率	
Load (%)	効率(%)
5	98.52
10	99.21
15	99.42
20	99.51
25	99.55
30	99.57
35	99.57
40	99.57
45	99.55
50	99.54
55	99.52
60	99.50
65	99.48
70	99.45
75	99.43
80	99.41
85	99.38
90	99.35
95	99.33
100	99.30

SDT-K-8734
(3/3)

Fig. 7 TDR HV/MV transformer efficiency curve. 66kV/6.6kV, 30MVA, 99.30% at rated capacity.

Efficency Curve

60MVA油入変圧器の効率曲線

2015年2月5日
三菱電機株式会社
系統変電システム製作所

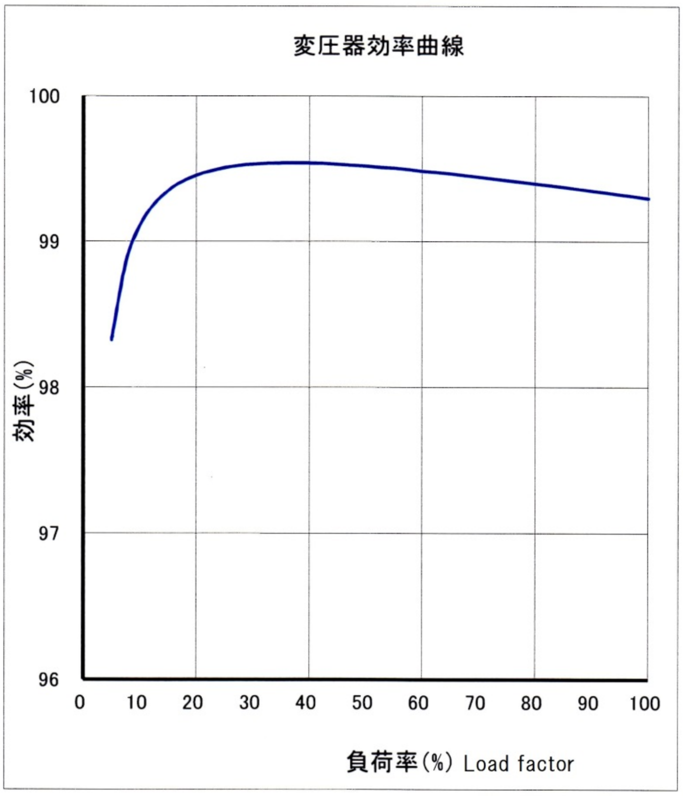
1. 変圧器仕様

三相，50Hz，導油自冷式，負荷時タップ切換器付，%Z＝15%，騒音値65dB，内鉄形
一次側：F168～R154～F140kV，星形
二次側：6.9kV，星形
安定巻線（三角形）付

2. 損失

無負荷損失（鉄損）　50 kW Iron Loss
負荷損失（銅損）　370 kW Copper loss
補機損失は含みません。
※損失は参考値であり，変圧器の仕様変更，詳細設計により変わる可能性があります。

3. 変圧器の効率曲線



変圧器効率	
Load（%）	効率（%）
5	98.33
10	99.11
15	99.36
20	99.46
25	99.51
30	99.54
35	99.55
40	99.55
45	99.54
50	99.53
55	99.51
60	99.49
65	99.47
70	99.45
75	99.43
80	99.41
85	99.38
90	99.36
95	99.33
100	99.30

SDT-K・8734
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Fig. 8 Green ILC transformer efficiency curve. 154kV/6.6kV, 60MVA, 99.30% at rated capacity.

4. Conclusions

The system that the author has proposed is the so-called “Green ILC system,” which offers a large reduction in the construction cost of more than twenty billion yen, and the operating cost will be more than one hundred million yen per year lower than the TDR system. In addition, the Green ILC system reduces the CO_2 emission by more than 5,000tons per year, a fact known by everyone.

We plan to use a superconducting cable for transmission and distribution. However, the cable loss in the Green ILC system is only 71kW. The author has some doubts whether a superconducting system, which requires cryogenic refrigerators can be sustained. This aspect must be very carefully studied.

Some people might worry about the direct transformation from 154 to 6.6kV. In fact, in Japan, many residential transformers from the nuclear power stations use 500kV/6.6kV. In addition, the Korea Proton Engineering Frontier Project has also a 154-kV/3.3-kV system.

The ILC system will provide large advantage derived from nuclear physics, but its need for huge consumption of electricity would be its weak point. Not only the construction cost but also the operation cost should be considered for the Green ILC, which the author has explained in details earlier.

Introduction of Friction Reduction Chemicals for water pipes
(Hiroyuki Nishi, Sin-Nihon Kucho)

1. Introduction

The method adding very small amount of pipe friction resistance reducing agent in the circulating water piping (Drag Reducing Additive: hereinafter referred to as DR agent), has been known technique to reduce the carrying power of the pump. This DR agent is used polymeric agent or a surfactant. Practical use of a surfactant has a long history, and has many examples, such as an increase in the navigation speed of the ship, improvement of the water discharge capacity for fire fighting, and oil pipeline transport capacity, they are examples of to transient flow field.

However, in the circulatory system DR agent will be destroyed its molecular structures by the mechanical shearing force such as a pump impeller, there is a problem of deterioration of the DR agent. Surfactant, on the other hand, because there is a regenerative capacity which will be mentioned later, become the mainstream in recent years of research carried out basic research and field tests in abroad. In the regions of the district heating pipes in Europe, it is used in practice. In Japan, it reached the stage of practical use from the basic research stage, the examples of the use have been increasing.

Shin-Nihon Kucho has about 15-year career and achievements with respect to DR agent introduction as energy-saving technology of air conditioning piping system. We introduce the basic characteristics of the DR agent description and example of application to the air-conditioning piping to the existing commercial building in this paper. It is our hope to help deep understanding DR agent for Green ILC WG participants, in turn, project promotion.

2. Mechanism of DR effect

When water is flowing in the pipe at a certain speed, water molecules at the pipe inner wall and the central portion disarray intensely in the flow, that is, the "turbulent flow" state. Most of the piping friction resistance rises due to the turbulent motion. Thus, by suppression of turbulence (laminating of the stream), the pipe frictional resistance can be reduced significantly. In Moody diagram showing the relation between the Reynolds number and the pipe friction coefficient in Figure 1, the friction coefficient of the turbulent flow is to close an extension of the diagram of the laminar flow zone shown by a broken line. This is a DR material has been developed for the purpose (the effect is called DR effect).

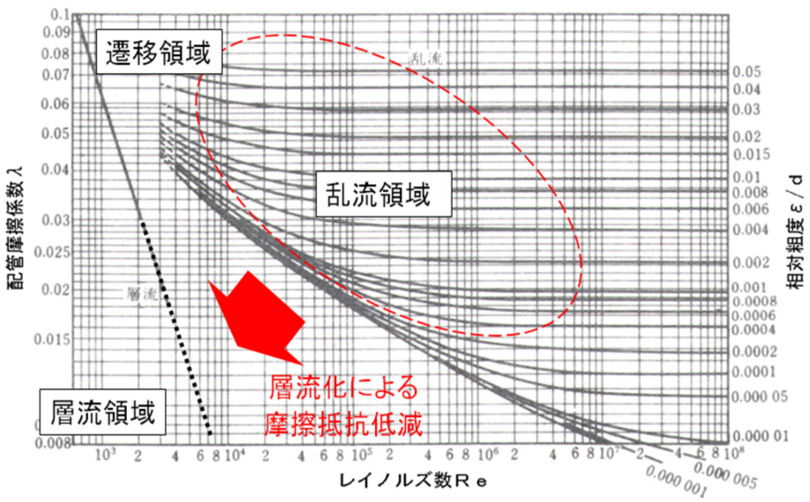


Figure 1 Moody chart

DR effect which was discovered by B.A. Toms in 1948 is a phenomenon which is also referred to as Toms effect. As the material of the DR agents, surfactants and polymeric agent is used. For example, by adding small amount surfactant to flowing water, collection of the surfactant molecules that form as if long chains as shown in Figure 2 (rod-like micelles) can modify the water flow to the non-Newtonian fluid, even rod-like micelles can be destroyed by mechanical external force, it will recover. While fresh water is Newtonian fluid is the constant viscosity regardless of the shear rate, the non-Newtonian fluid viscosity varies with shear rate. As shown in Figure 3, pipe flow state is almost the same as a fresh water at near-wall where is a large shear rate with small viscosity, at the center, since the place is in a large viscosity with small shear speed, the flow become small disturbance massive flow, then, turbulence is suppressed and the pipe frictional resistance is reduced.

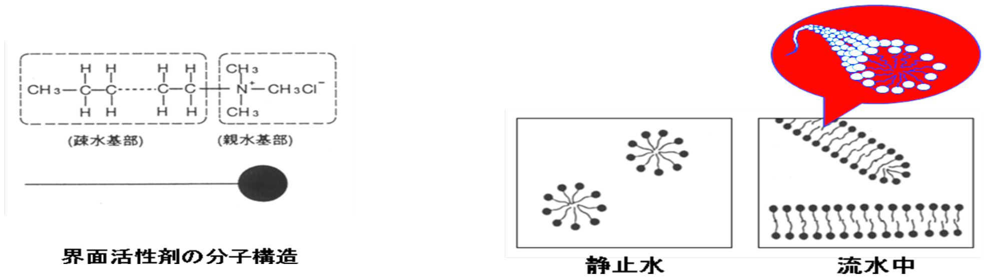


Figure 2 the molecular structure of the surfactant, and rod-like micelles in the flowing water

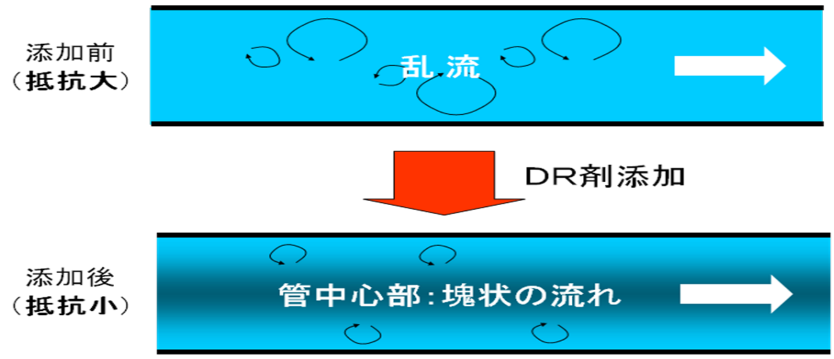


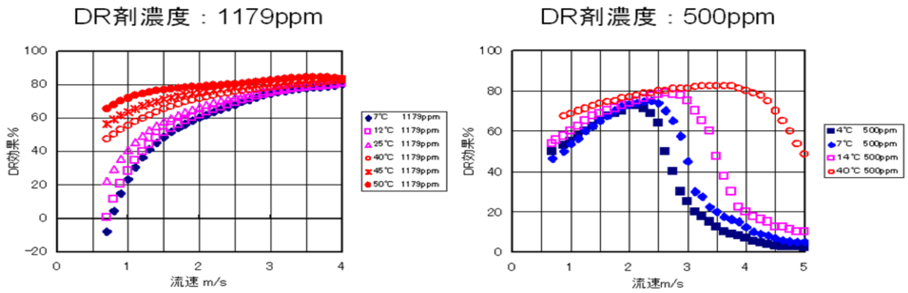
Figure 3 changes in the pipe flow state

3. Characteristics of DR effect

DR agent that we are using, is cationic surfactant of Ethoquad system, added counter ion conducive to form rod-like micelles, it is a product that also has anti-corrosion effect. DR effect determine mainly "flow velocity in the pipe", "the temperature of the circulating water", and "concentration of DR agent". As "flow velocity in the pipe (1m / sec ~ 4m/sec)" is faster, and as "the temperature of the circulating water (5℃ ~ 65℃)" is higher, and "concentration of DR agent (stock concentration 500ppm ~ 1,000ppm)" is higher, DR effect tends to increase.

Figure. 4 is a data of DR effect in the straight tube portion with stock concentration of DR agent 1,179ppm and 500ppm, has to organize the DR effect by the pipe flow velocity and temperature as a parameter. The DR effect is approximately up to 80% where DR effects increase by an increase in flow speed and temperature. Although, at the low concentration 500ppm, DR effect is greater at low flow rates range, if it exceeds a certain limit in the high flow rate region, the rod-like micelles is destroyed in a turbulence intensity and then DR effect is lost. Also in the joint portion of the curved portion, because of large turbulence intensity originally, DR effect can not be expected.

In addition, both of straight tube portion and the joint portion, for viscosity increase due to DR agent additive, sometimes DR effect is negative at below 1m/sec of the low flow rate region, where the viscous resistance becomes dominant.



$$DR\text{効果}(\%)=\left[1.0-\left(\frac{\text{DR溶液の配管摩擦抵抗}}{\text{清水の配管摩擦抵抗}}\right)\right]\times 100$$

Figure 4 DR effect of straight pipe section

The DR effect is up to 80% in the straight pipe section, on the other hand, for the effects of the resistance in the joint portion of and the resistance of the equipment inside are dominant in DR effect of the entire piping system, overall DR effect is shown in Figure 5. DR effect of the entire piping system will be determined by the ratio of the DR effect of the straight pipe portion resistance to total resistance (corresponds to a pump total lift).

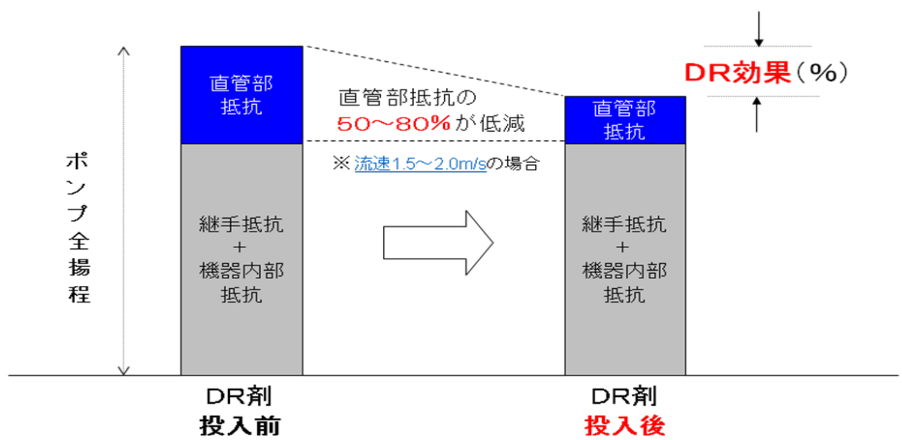


Figure 5　overall DR effect of piping system

Figure 6 shows the effect of DR additive to fin and tube type air/water heat exchangers which are used in air-conditioning fan coil unit. DR effect, because it is brought by the turbulence suppression, cause a reduction in heat exchange efficiency if generated in the heat exchanger tube. The heat exchange efficiency is hardly reduced because DR effect is relatively small in the case of cold water, reduction in heat exchange efficiency due to the relatively large DR effect is assumed to have occurred in the case of hot water. In DR agent case study on our company's existing commercial building, reduction of heat exchange efficiency is not observed for cold water heat exchanger.

However, decrease in heat exchange efficiency due to the DR effect in the internal heat exchanger can not be simply assessed, because of dependence on the diameter of the tube, the length of the straight pipe section, also the influence of the shape of the inner wall. For applying the DR agent to specialized equipment which is different from the commercial air-conditioning, it is expected to require more detailed examination and verification.

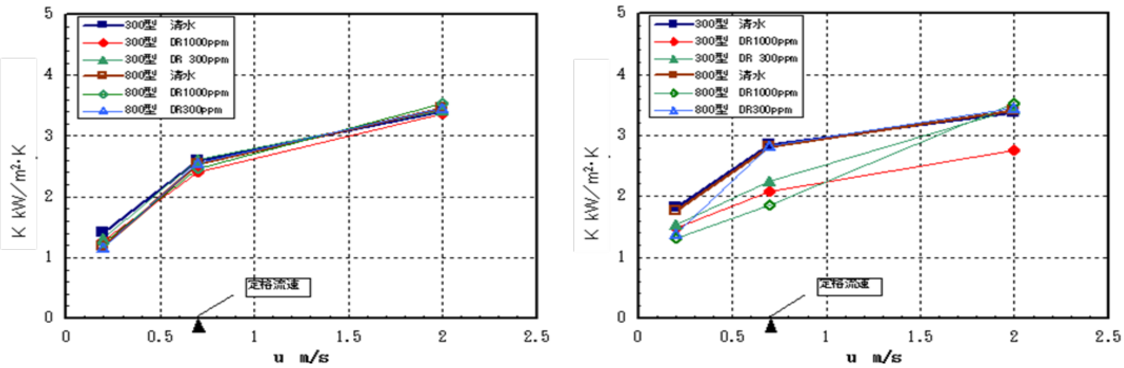


Figure 6 impact on the heat exchange efficiency of the fan coil unit

4. Input conditions of DR agent

Are shown below nine conditions (① ~ ⑨) is a study item at the time of the DR agent input for the existing business building. Since ① ~ ③ is a necessary condition, it can not be applied on as long as it does not meet this. ④ ~ ⑨ is not a necessary condition, since the higher the initial cost and running cost, since the cost-effective worse, the possibility that results as the input becomes unsuitable.

As for ①, the circulation of the water is significantly inhibited by capturing the gas bubbles into the circulation water, if it is an open circuit rather than a closed circuit. It should not be applied on because there are cases in which bubbles are blown out from the expansion tank. For ②, when components such as iron and zinc of the circulating water is at high concentrations, the expression of DR effect is interfered. In addition, since surfactant component is adsorbed on the rust that is generated inside the pipe, and is to peel off the rust which may inhibit the flow of the circulating water, DR agent can not be introduced into the system piping where internal corrosion has progressed. For ③, because the circulation amount of water due to the reduction of piping resistance increases only by applying DR agent, the carrying energy of the pump is increased. Therefore, it is essential to control or to adjust so as to be a proper flow rate by the inverter or something.

· DR agent conditions for input (for the existing business building)
① it is a closed circuit.
② water quality and piping internal corrosion is within the allowable range.
③ it is a inverter control pump (or manual inverter adjustment).
④ the flow rate is relatively fast in the system (more than 1.5m/sec).
⑤ resistance ratio at straight pipe section is a relatively large in the system.
⑥ chilled water system or similer piping system (hot water system is unsuitable).
⑦ no using rust inhibitor incompatible with the DR agent.
⑧ measurement environment (pressure, flow rate, the amount of power) are in place.
⑨ the pump has a mechanical seal.

5. Case example of DR agent introduction

We introduce the reality of DR effects and energy-saving effects based on the real case, although it is not possible to state the magnitude of DR effects unconditionally, where the air conditioning piping system has a variety of characteristics, such as the ratio of the resistance for straight pipe section and the rest (resistance of internal joints and equipment) depending on the design of the building equipment, difference of pipe flow velocity, flow rate change throughout the year, and properties such as temperature.

Building as a target of case studies, which is the 20th floor above ground, in the total floor area of about 50,000m^2 merchandise store building, is a DR agent application example to a heat source water piping system (for water heat source package air conditioning), where heat source water pump is a 15kW x 3units (parallel operation and constant control of discharge pressure).

In Figure 7, it is shown piping resistance curves, two of the upward curves showing the measured result of the circulation flow and the pipe pressure loss of the input before and after the DR agent of the building. At the rated flow rate at three pump operation (circulation flow rate 100%), the piping pressure loss after turning-on (DR solution) has been reduced by 13% compared to before (pure water). Reduction of the pipe pressure loss, that is, the DR effect.

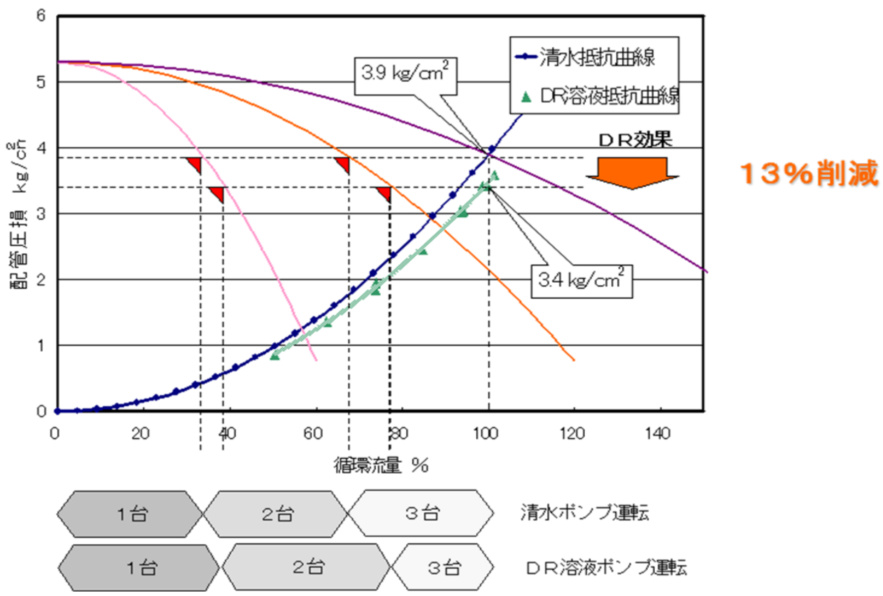


Figure 7 actual measurement result of the circulation water and the pipe pressure loss

Figure 8 is a plot obtained by actually measured the power consumption and the circulation flow rate, based on the measurement of the pressure and the flow rate of input before and after shown in Figure 7, in a state after the appropriate control settings change. Although, for the circulation flow rate less than $80m^3/h$, it was about 13% of the energy-saving effect with one pump operation before and after, it was about 37% of the energy saving effect together with operating unit reduction effect, for the circulation flow rate around $100m^3/h$ and since after applying DR solution operating pump units became one. The energy-saving effect through the year is determined by whether how much of the load flow rate change occurs in how much of the frequency, since circulation flow rate is constantly changing in the actual operation.

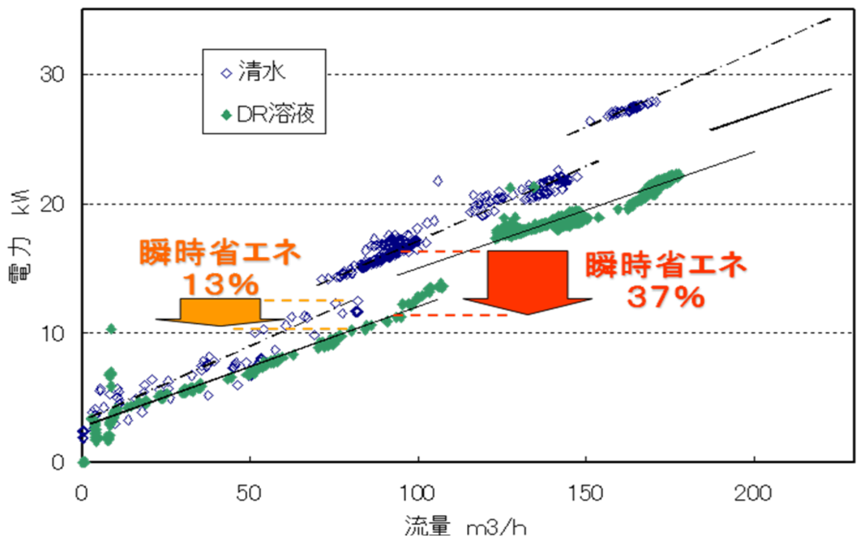


Figure 8 actual measurement result of the circulation water and the pump power consumption

In Figure 9, the occurrence of each load flow rate (in every 10%) when the maximum flow rate designed to be 100% are shown in the bar graph by a respective measurement of one year before and after the introduction, in the case of the same building that was introduced case above. Total operating time of year was a 5,475h, one pump operation time after application was increased to 3,534h, where an operating time of the before was a 2,776h, and 3 pumps operating time of the before was 557h was reduced to 37h against. In other words, it can be seen a number of operating unit reduction coming from the effect that the average number of operating units of the pump was decreased.

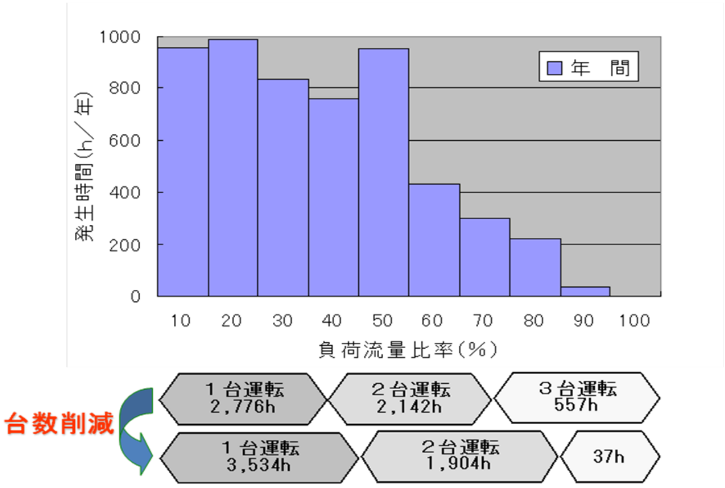


Figure 9　pump operating time with each load flow rate of year time occurrence

When we estimate the power consumption of the year for each load flow from Figure 8 and Figure 9, it is Figure 10. From this result, the annual power consumption 72.8MWh/year before application, it becomes 52.2MWh/year after the application, and energy-saving effect of the year was about 28%. In particular, it is read a large energy-saving effect in the load flow rate ratio of 40% to 50%.

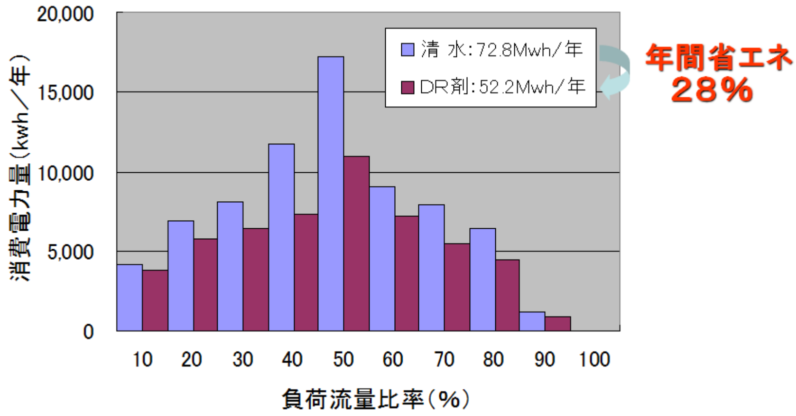


Figure 10 annual power consumption of each load flow rate

6. Summary

This paper is assumed the DR agent application to the air conditioning piping for the existing business building, the findings are summarized below.

(1) it is necessary to examine well the appropriateness of the target system before input.

(See "Conditions for DR agent application ① ~ ⑨")

(2) Energy saving effect can be easily obtained as the straight pipe section resistance ratio is large. (See Figure 5)

(3) energy savings can be obtained for the first time by carrying out appropriate pressure-flow rate adjustment.

(4) The proper pressure and flow rate adjustment is required overall engineering design based on actual measurement.

(5) hot water system has a possibility that the heat exchange performance degradation occurs. (See Figure 6)

(6) After application, the DR agent concentration management is important.

Nevertheless the auther's understanding of the ILC is not sufficient, the challenges of adopting the DR agent in this project are listed three below;

(1) Acquisition of basic characteristics data in the case of DR agent charged into a large diameter pipe.

(2) Design of the resistance ratio of the straight pipe part and the optimum pipe size in consideration of the energy-saving effect.

(3) Verification and its counter-measure to radio-activation of DR agent.

Reference

[1] Iguchi, Kudo: Evaluation of piping resistance-reducing agent (the 1-3 Report), air conditioning and sanitary engineering Association, academic lecture Papers (2000-2003)

[2] Iguchi: practical evaluation of the pipe friction resistance reducing agent, piping technology October 2003 issue (Nihonkogyoshuppan)

High efficiency operation of Data Center
(Osamu Takehisa, NTT facilities)

1. Introduction

Data center that houses the computer and data communication equipment has become an important infrastructure that is essential not only for the company but for the entire society. However, power consumption of the data center is increasing year by year. Figure 1 shows the amount of heat generated per rack of ICT equipment by the investigation of ASHRAE. According to the 2012 the latest survey results, the amount of heat generated by the ICT equipment is further increased, it has become a 40 ~ 50kVA per rack with a maximum, and there is a prediction that extends to about 10-fold in 2000 to 2020. Power consumption of the data center will consume the power of 5-10 times more compared to the same scale of the office building.

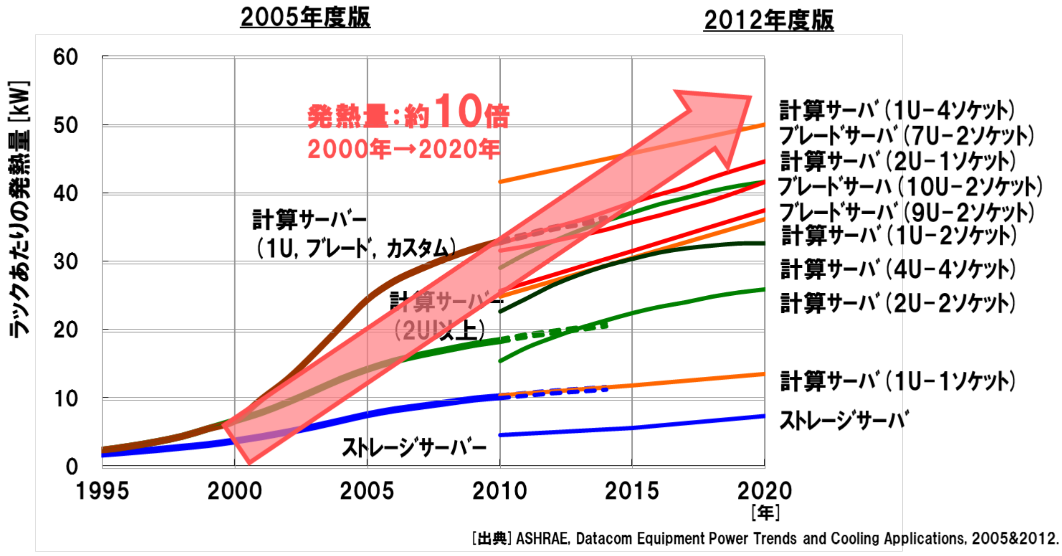


Figure 1 calorific value trend of ICT equipment

More recent price hike of electricity prices is multiplied by the final blow, power cost reduction has become the greatest challenge of data center business operations. (Figure 2)

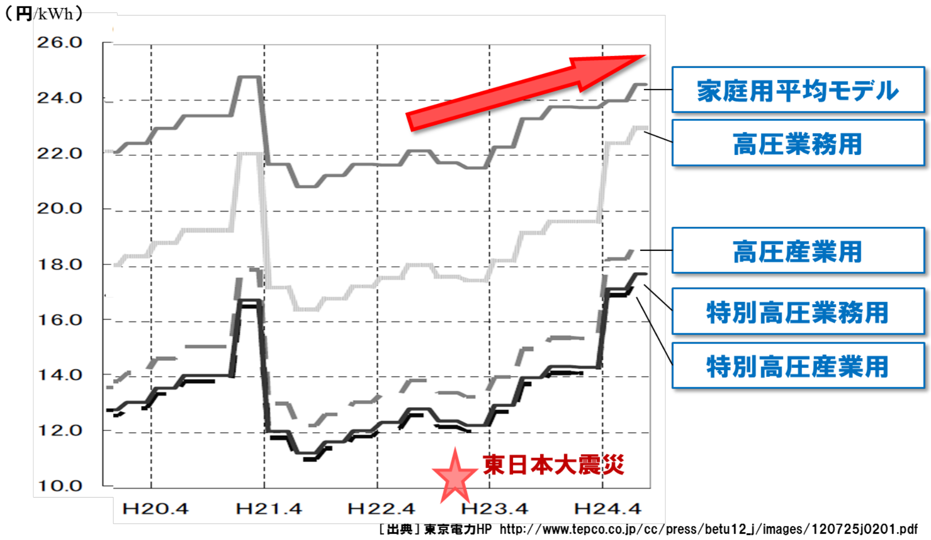


Figure 2 Changes in model electricity prices in TEPCO

The power consumption breakdown example of a data center by the Uptime Institute and the McKinsey survey is shown in Figure 3 (The Uptime Institute, The Invisible Crisis in the Data Center 2007). ICT equipment is 56%, the air-conditioning power is 33%, the power supply loss, lighting and others become 11%. To reduce power consumption in this situation, the following three points are important. First, to improve the air conditioning efficiency. Second, to improve the power conversion efficiency. The third is to do optimization throughout total system including ICT equipment, air conditioning, and the power supply system.

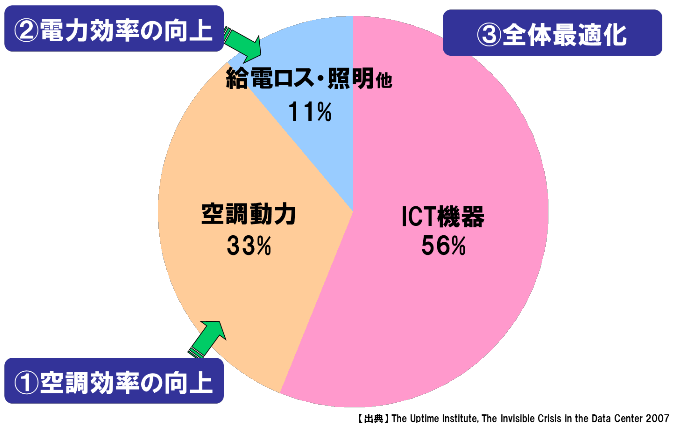


Figure 3 power consumption breakdown example of a data center

In Figure 4, it shows the breakdown of the data center facilities investment. This is the average for conducted hearings on the data center operators by ourselves. It finds that about 75 percent of the capital investment is being used to maintain the existing data center (surveyed 38 companies in December 2012 implementation). The old data centers faced many challenges, because they are unable to stop the service to the equipment specification renewal, and can not be extended by the power capacity shortage despite a space in the server room, etc.

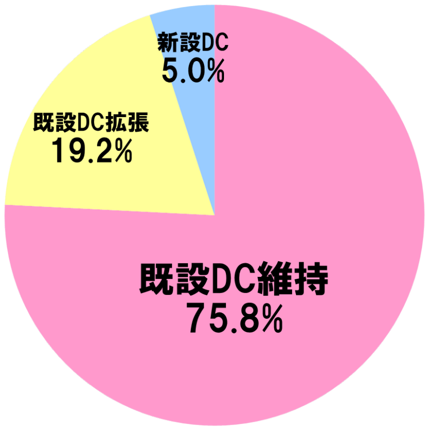


Figure 4 the capital investment breakdown of the data center

NTT Facilities will maximize the value of the data center from the multilateral point of view, by a combination of technology that has supported the communication of Japan and building and energy technology, and by solving the issues for reduction of power costs and personnel expenses, equipment and buildings of aging measures, the issues such as response to the scalability. In addition, we support cost reduction for electricity charges and equipment of the data center, and provide a variety of solutions from the power-saving products such as LED lighting, system development to realize the energy saving, and to consulting, since the data center is to continue to operate a long time, especially energy-saving and cost reduction becomes important. NTT Facilities has carried out about 30% of the design and construction of the entire domestic data center, in 2000 or later, there are building experience about 40 buildings of large-scale data center of more than 5,000 square meters. Also, in addition to the 24 hours operation a day and 365 days a year by the advanced systems that make full use of ICT, we have maintenance staff of experienced professional, which is located across the country about 260 locations of maintenance bases, to deal with rapidly and eligibility at the time of trouble. Overseas, we have the local subsidiary in the United States West Coast and in Beijing, the branch in Singapore, the partner construction company of the data center in Thailand. There are consulting experience at about 120 sites in the world 30 countries, the design, construction and O&M records in Singapore.

This time, focusing on the energy and cost savings from a variety of solutions, we introduce the solutions for improving the power efficiency and improvement of the air-conditioning efficiency. For the solution for air conditioning efficiency, airflow control system for ICT equipment "aisle capping", smart air-conditioning control system for the data center "Unified Cooling", introduction of efficiency improvement of air-conditioning system by outside air use "indirect outdoor air cooling type of FMACS hybrid", are introduced. For the solutions of power efficiency improvement, high-voltage DC-current system for ICT equipment "HVDC (high voltage DC power supply)" is introduced.

2. Solutions for improvement of the air-conditioning efficiency

There is different cause that is not able to efficient air conditioning in the actual data center. As a typical example, the following three are mentioned. The first one, that cold air to cool air for cooling is inhibited, and does not reach to the server. The recent years of data center take the method which is often supplying the cold air from the double floor in the double floor system, however, in the double floor, it has been laying the cable to the ICT equipment, and is often stacked high. Also, the cables being made replacement of ICT devices often can not be removed and buried in another cables. As a result, when the replacement of ICT equipment is followed by cable is piled high, it has often occurred that cold air to the ICT equipment is unable to supply. (Figure 5)

Figure 5 inhibition of airflow (cold)

The second one, adverse heat effects to ICT equipment will occur, by the hot spot and heat accumulation where required cold air can not be placed and the exhaust heat of ICT devices are wrapped around (when it severe, server is down). (Figure 6)

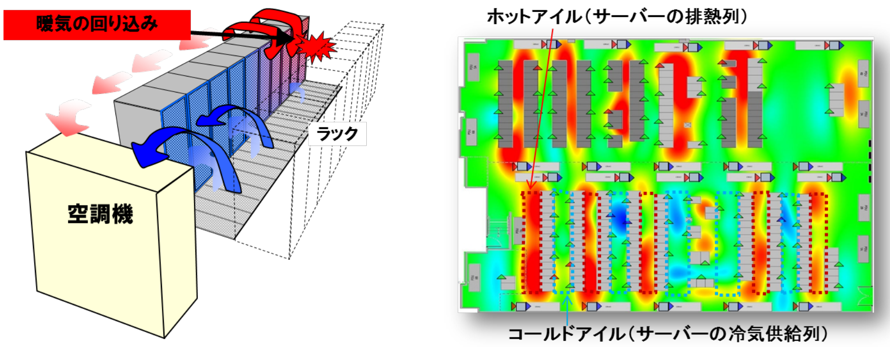


Figure 6 inhibition of airflow (cold)

The third one, the server often become hot at the top, being made of good cooling in the bottom, since it has about 2m height. (Figure 7)

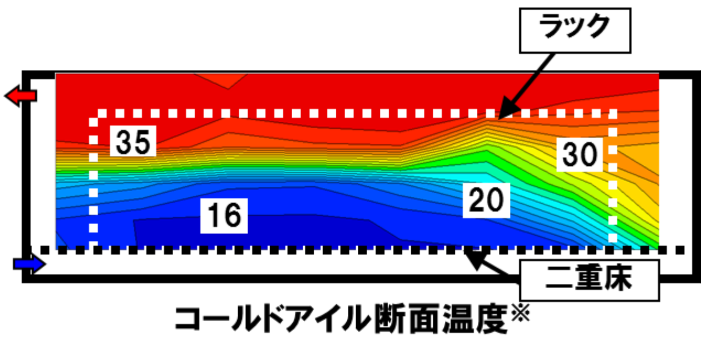


Figure 7 the upper and lower temperature difference at the suction surface

To eliminate hot spots, as a countermeasure 1, is a method of increasing the air volume of the air conditioner cooling, however, energy saving as a whole can not be achieved for sending cooling air flow more than necessary in other locations. As a countermeasure 2, there is a method of lowering the set temperature of the air conditioner, however, energy saving can not be achieved to lower the temperature in the same or also required elsewhere. (Figure 8)

Therefore, here we will introduce the solutions that lead to cost reduction and energy saving.

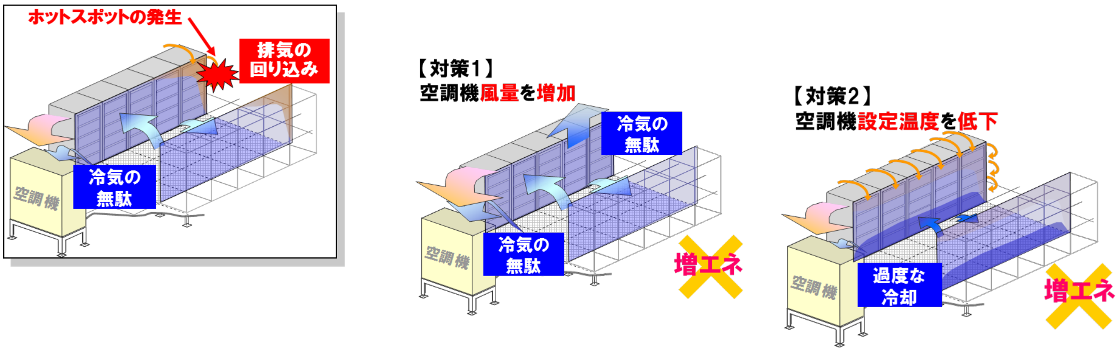


Figure 8 countermeasures for hot spot

2-1. Airflow control system for ICT apparatus "aisle capping"

The aisle capping, is an airflow control technology to realize the efficient air conditioned environment and is a solution that can be both energy-saving and high reliability in the data center, by partioning a rack passage by walls and roof, and by separating physically the exhaust the (high-temperature) of the IT equipment from the air supply (low-temperature) to the IT equipment. As energy saving effect as a feature, by improving the supply air volume reduction and operational efficiency from the air conditioner, the air conditioning power can be reduced up to 20 percent. In addition, by eliminating the hot spot of the cold aisle, a good air conditioning environment can be achieved. And it has a high seismic performance, mitigation of the supply temperature rise in the event of a power failure. The top panel is removable and can be easily maintained. (Figure 9) (Figure 10)

Figure 9 inhibition of airflow (cold)

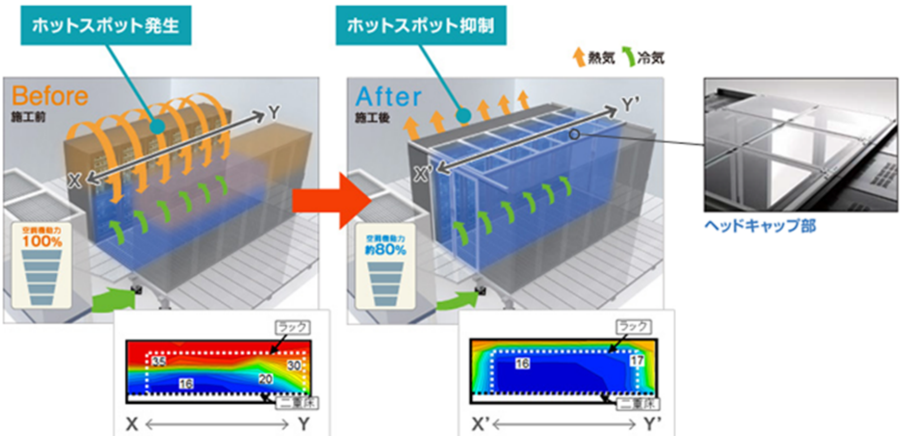


Figure 10 Inhibition of airflow (cold)

Also, by calculating the pressure distribution under the floor tailored to the air conditioner and underfloor availability, and by calculating the blow-off distribution commensurate with the airflow in need or with heating value of the equipment, the equipment necessary aperture ratio of the double floor panel and its deployment plan are obtained for properly cooling, and it will be able to suppress the air volume of the air conditioner. (Figure 11)

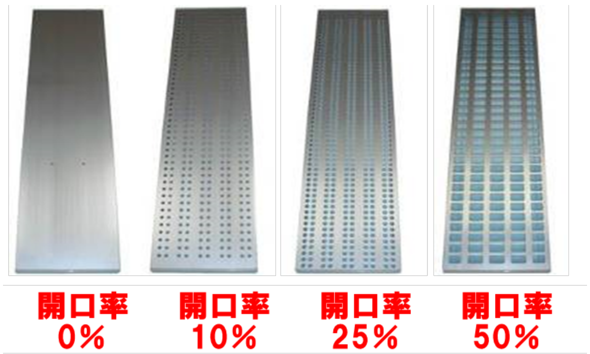


Figure 11 porous double floor panels with different aperture ratio (aperture ratio: 0% to 50%)

Then, by mounting the blank panel that blocks the hot air flowing through the gap in the rack to the cold aisle to the place of not mounted server equipment in the rack, it is possible to enhance the control efficiency of the aisle capping. (Figure 12)

Figure 12 inhibition of the air flow (cold air)

2-2. Data center for smart air-conditioning control system "Unified Cooling"

Since in large data centers scale power consumption increases, and for the air-cooled package air conditioning system there is a possibility that can not be installed outdoor unit to the outdoor space, there is a growing tendency for cold water use air conditioning system is adopted. In chilled water use air conditioning system, there is divided three functions, the chiller cooled the water (heat source system), a pump for circulating the water (water-based), and air conditioner which performs cooling installed in a server room. These chiller, pump, and air conditioner, it is often that consists of different manufacturers, it can not be cooperation operation between devices. Therefore, cold water temperature and water supply pressure (water amount) of cold water made by the chiller is operated at a constant set value assuming the maximum cooling load, if the load is not a maximum value, such as a low operation rate of the ICT device, it tend to consume power more than required and to decrease the efficiency. Power consumption of the chiller pump accounted for 60% of the power consumption of the entire water-cooled air conditioning system, energy conservation has become a major issue. Therefore, Unified Cooling® is ever performs chiller and pump integrated control that was operated at a constant set value, to reduce power by adjusting the flexible settings. The dedicated developed controller, regardless of the building new construction or old, unifies the information of chillers, pumps, and integrating information of the air conditioner into BACnet which is a standard communication protocol specifications of the BAS, and controls the settings of the chiller pump by monitoring the operating temperature and humidity and air conditioners in the data center. (Figure 13)

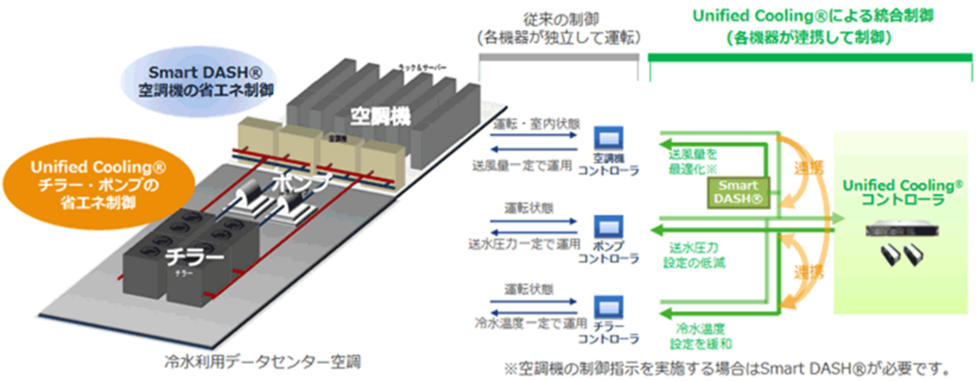


Figure 13 Overview of the Unified Cooling®

In addition, Smart DASH collect the suction temperature data of ICT equipment, by the wireless temperature sensor installed in the server rack and the server room, individually automatically controls each of the air conditioners on the basis of the analysis result of collected data. Until now adjustment of the temperature environment has been done manually by a technician-operator, etc., Smart DASH has a learning function, and precision of air-conditioning control is improved through the utilization of a continuous operation, by dynamically respond to the amount of heat change generated by the server, achieve a higher energy efficiency optimum air. It is noted that the air-conditioning control, wireless communication and BACNet, the communication protocol, such as MODBUS are used. (Figure 14) (Figure 15)

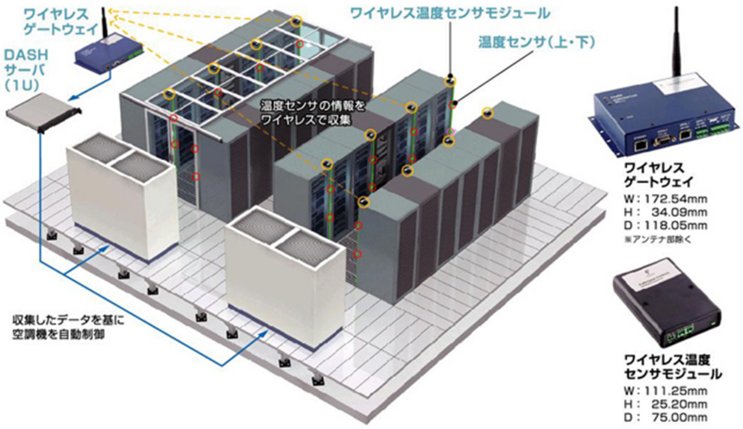


Figure 14 System configuration in Smart DASH

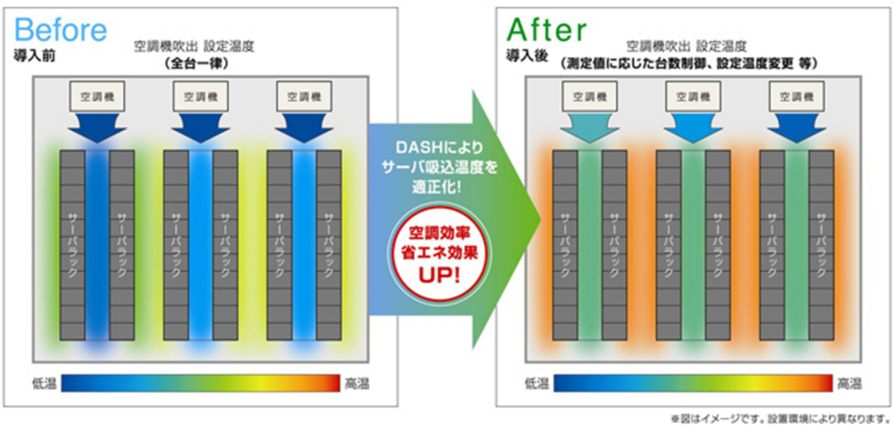


Figure 15 Benefits of Smart DASH

By these system, highly reliable and highly efficient integrated air conditioning control can be achieved, and up to 30% power consumption of the chiller and pump can be reduced. In addition, by combining the data center air conditioning automatic control system SmartDASH® of our products, it is possible to make all energy saving for air conditioners, chillers, pump, 2.5 times saving as compared in the case of use SmartDASH® only, it will reduce power consumption up to 30 percent of the entire system of air conditioning. (Figure 16)

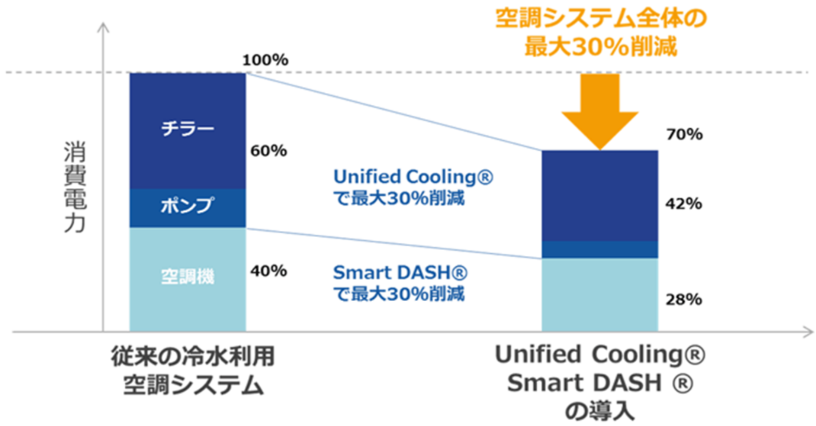


Figure 16 effect of reducing power consumption of the air conditioning system

2-3. High efficiency air conditioning system "indirect outdoor air cooling type FMACS hybrid" through the use of outside air

Generally, direct outdoor air cooling method using low temperature ambient air (Figure 17-1) has a case that it is necessary of humidity control to avoid corrosion of the electrical circuit board due to impurities, such as outside air dust and sea salt particles, and in accordance with air introduction amount. With clearing these challenges, we have developed FMACS hybrid (Figure 18) as an indirect outdoor air cooling type air conditioner suitable for data centers where high energy efficiency is required (Figure 17-2). This air conditioner comprises a compressor and a refrigerant pump, a less indirect outdoor air cooling to reduce the influence of external air quality, and high efficiency while ensuring high reliability and availability are realized. The compressor is stopped in winter and in the interim period when the outside air temperature is low, by performing the outside air cooling operation that circulates the coolant in the coolant pump, operation efficiency is greatly improved, since the power consumption of the coolant pump is much smaller than compressor used in a conventional air conditioner. Using the present air conditioner, the annual power consumption and annual CO_2 emissions related to the data center air conditioning are up to 54% reduction (estimated result by the standard meteorological data of Sapporo) as compared to the general computer room air conditioners.

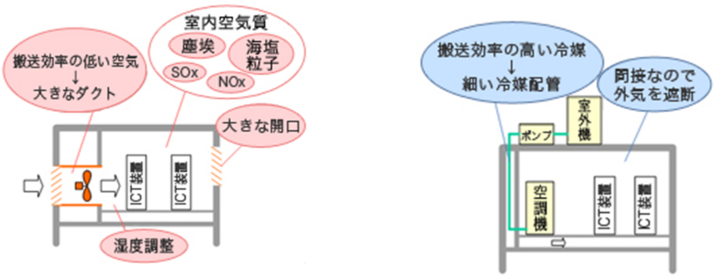


Figure 17-1 direct outdoor air cooling system, Figure 17-2 indirect outdoor air cooling system

Figure 18 FMACS hybrid appearance

As a reference, for condition of the outside air environment of the location, possible year time of direct outdoor air cooling at 24℃ operation data center estimated from meteorological data of each city, is 5,000hours in Sapporo, 3,500hours in Tokyo. However, because it is necessary to adjust the humidity, it needs to be careful that it is not all for energy-saving time. (Figure 19)

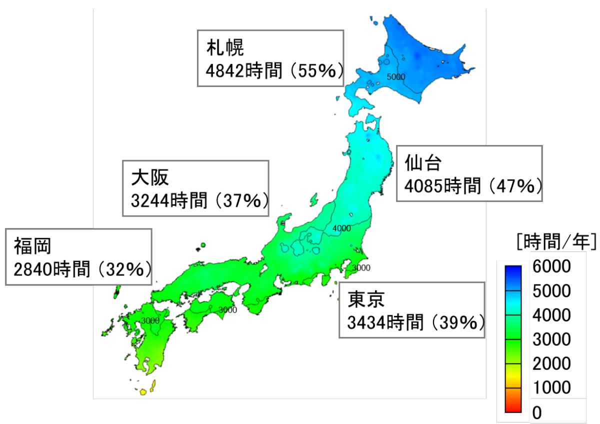


Figure 19 estimated operation time of outdoor air cooling

3. Solutions for improvement of power efficiency

Power supply system, which has been utilized in the central telephone office as a reliable power supply, are deployed in the data center, in recent years, in consumer electronics, also to distributed power supply, etc. Although previously mentioned, in which the power consumption of the data center is expected to increase more and more in the future, in the NTT Group, as part of the "DC power supply promotion of initiatives policy", as a friendly power supply system to the global environment we are promoting the further research of the DC power supply system. So, we will introduce the solutions related to power efficiency improvement.

3-1. ICT equipment high-voltage DC system "HVDC (high voltage DC power supply)."

General ICT devices converts AC power into DC, and operates by further converts the voltage. The ICT equipment in the data center is connected always via a UPS (uninterruptible power supply). Also, since in the UPS the conversion of the AC/DC, and the DC/AC performed, four times in total including conversion in the ICT equipment takes place in the data center. In contrast communication system used in NTT, by feeding the first from the DC 48V in order to reduce the power conversion to twice, a mechanism to reduce the cause of energy loss or damage has been employed for a long time. The company, applying this mechanism, in order to cope with recent ICT devices large power consumption, has provided the HVDC power supply system that enhances the voltage of the supply power to 380V since 2011. (Figure 20)

Figure 20 large-capacity HVDC rectifier system

Compared with conventional UPS systems, by introducing the HVDC power supply system, up to 20% energy saving and 40% space saving is achieved. Cost is also served at almost the same. (Figure 21)

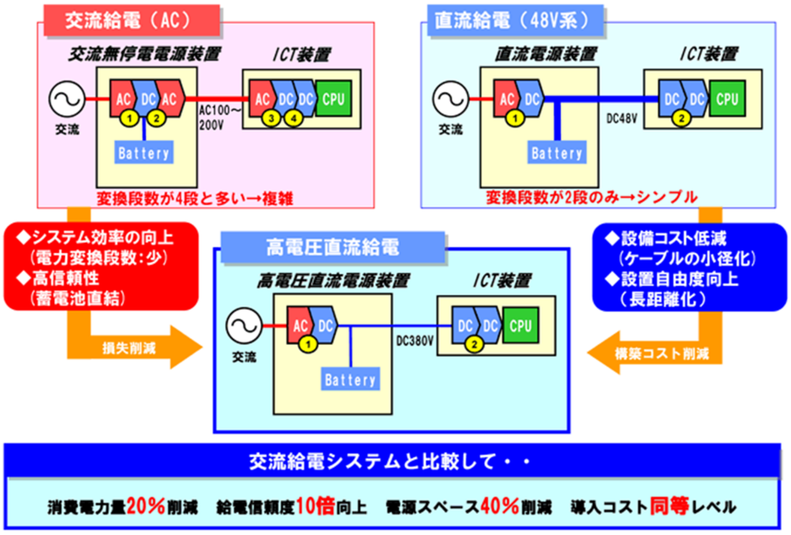


Figure 21 benefits of the high-voltage DC power supply

Mounting in a rack by the 2013, migration apparatus which can convert the voltage to fit existing ICT equipment (AC100V/200V, DC48V) is also on sale, and is to improve the flexibility of introduction for the spread of HVDC. On the other hand, we have been also promoted movement towards international standards, ICT equipment manufacturers to sell the HVDC-enabled products are gradually increasing. In addition, such as there is also a movement to standardize the connector or plug of the power, it is expected the spread in the future. (Figure 22) (Figure 23)

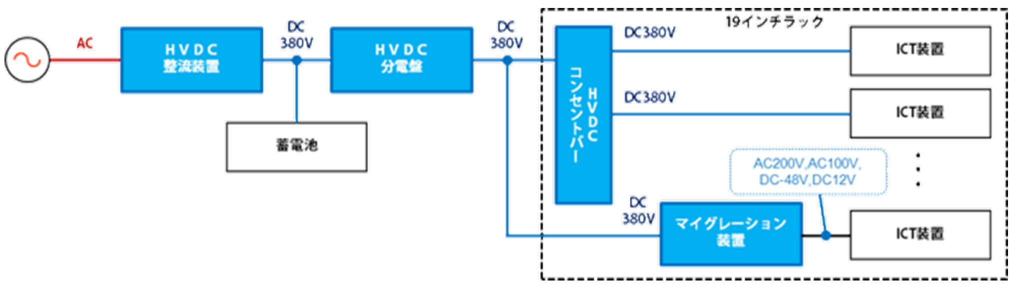


Figure 22 Overview of HVDC power supply system

Figure 23 migration devices, and HVDC outlet bar and power plug

As an example of an introduction effect of HVDC, in the system of Figure 24, comparing HVDC power supply system efficiency with the AC power supply system, it is improved by 11%, and there is a reduction of 108000kWh per year of power consumption. As a result, about 1.3-million-yen reduction in electricity rates over the years, and there is a reduction of CO_2 emissions by about 36.5t. This is equivalent to the CO_2 absorption amount of forest 10.2ha (2.2 times Tokyo Dome area). (Since this introduction example is one of the cases, at the time of the actual introduction system configuration quantity, etc. are different, then result might be different.)

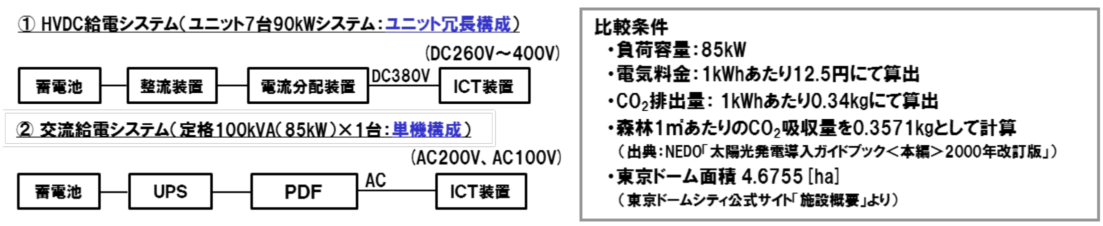


Figure 24 System Comparison (Example)

Table 1 power consumption and comparison of electricity prices

電源システム	HVDC 給電システム	交流給電システム（UPS）	差
年間消費電力量（万ｋWh／年）	85.2	96.0	10.8 万 kWh
年間電気料金（百万円／年）	10.7	12.0	130 万円
年間 CO_2 排出量（ｔ／年）	289.7	326.2	36.5 ｔ

4. For the future

In recent years, we often hear DCIM as data center-related keywords (Data Center

Infrastructure Management). Data center operators, by DCIM introduction, has the advantage of energy conservation and cost reduction. The DCIM is integrated management method for ICT equipment, power supply equipment, air-conditioning system, the resources that make up the data center such as rack space etc., and for facility management techniques to support the optimal operation of the data center. In our company regarded the followings as "DCIM", that is, from the design, construction and procurement, to operation, maintenance, and analysis, and the "management cycle" itself, including the planning and consulting. From "Connecting", "Accumulate", "Showing (the show)" various data to the "Use (to find customer value)", and further to realization of the "Prediction", "Action", we have strength to realization of DCIM where no other companies having, then we will further study and as able to offer.

Smart Community
(Takahumi Shimokochi, Takenaka)

1) ILC and smart community

Although there is no clear definition against smart community, in the "Basic Energy Plan" [1] of Japan, it is marked as "a certain scale of the community, while using a distributed energy such as renewable energy and cogeneration, and building through energy management systems that utilize technology such as IT and storage batteries, comprehensively manage the energy demand in distributed energy systems, as well as optimize the utilization of energy, a new social system incorporating also other life support services. " In addition, Figure 1 is shown as an image [2].

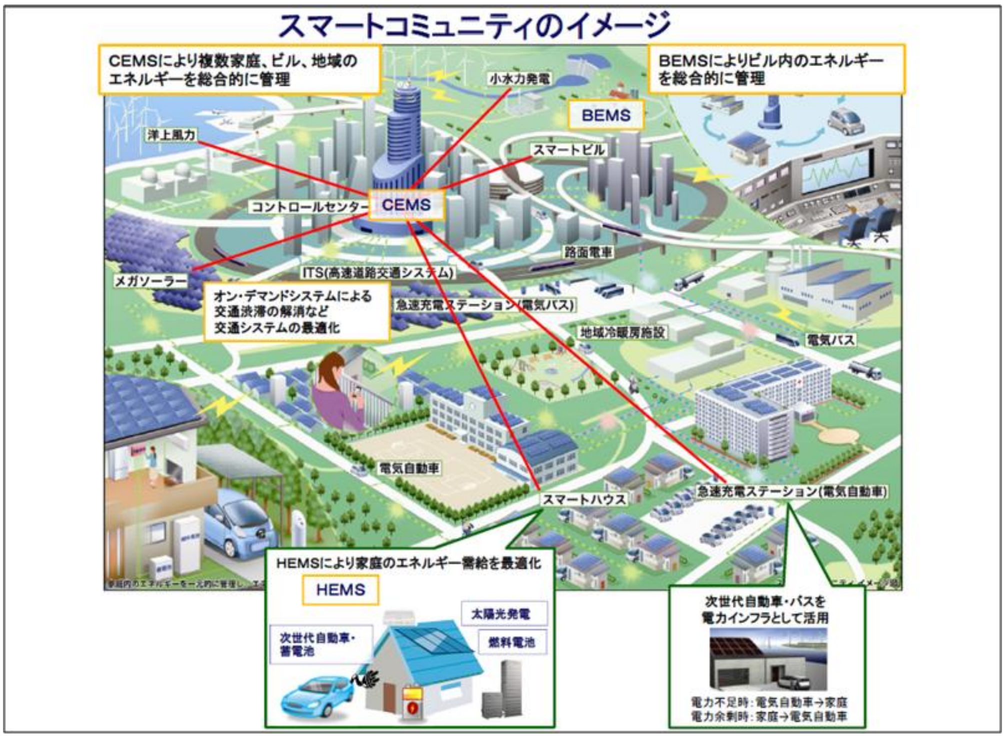


Figure 1 image of smart community [2]

In the ILC, about total floor area in the central campus and the experimental site 254,000m^2 of ground facilities have assumed, international science and technology research sphere, such as shown in Figure 2, is envisaged [3]. Campus building with smart community, town planning is an important point of view also in the ILC. We will introduce a demonstration cases and building cases which Takenaka is doing in the following.

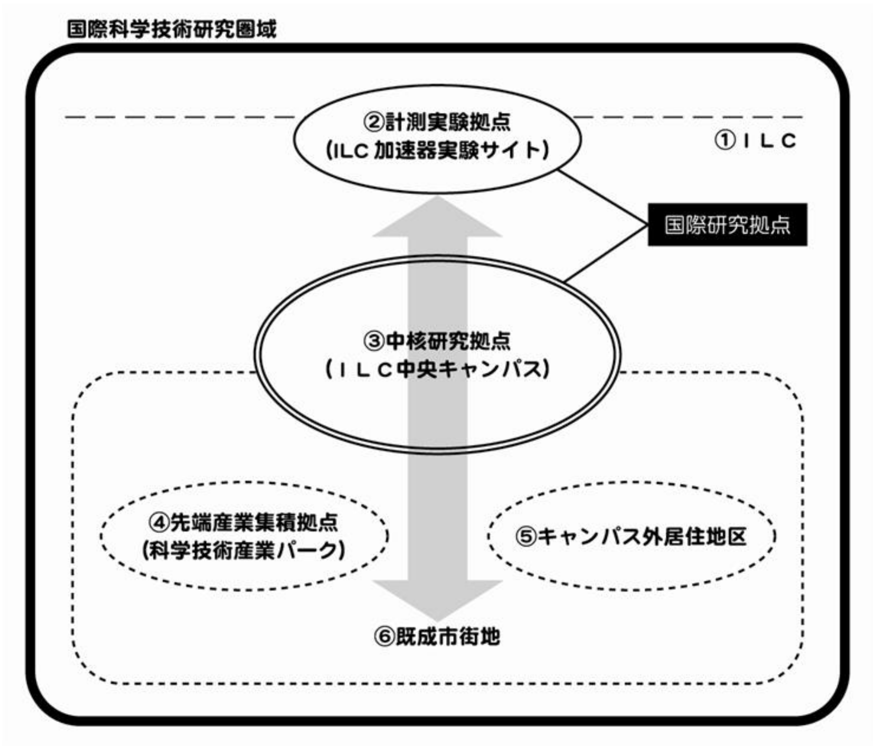


Figure 2 Deployment image of ILC international science and technology base to construct a research area and District [3]

2) Energy management that utilize cloud

"Building communication system", information and control platform of building equipment that was developed by Takenaka, is a system to capture the changes in the building and out of the environment and information, to create the cooperation of the building and "people" by lobbying to users, and to activate the activity of the "people" and the "town".

"Building communication system", creates added-value such as the automation of control to realize the energy saving and demand response and productivity improvement by analysis and show of various sensor information, and aims the creation of convenient and attractive space for the user.

In addition, not only the building itself, it is possible to centralize the information of city block area, and to contribute to the rationalization of the various management, such as optimization of energy in the area, the formation and activation of the area within the community. Through this system, by cooperating people such as landowners, tenants, visiter, the system operator, a sustainable area management can be build. (Figure 3)

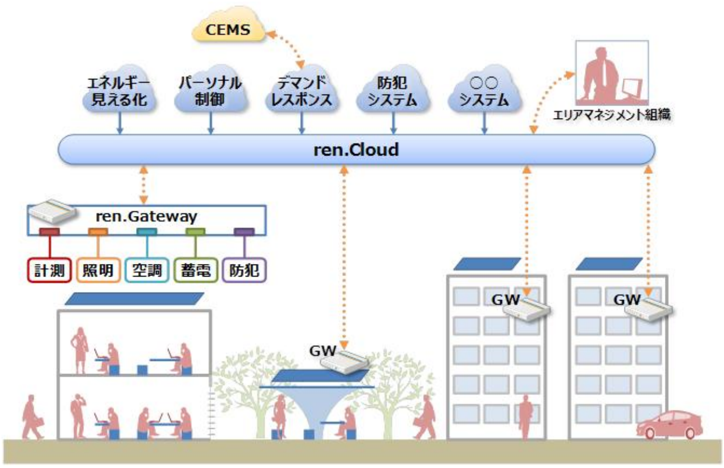


Figure 3 energy management that utilize cloud

3) Energy management by regional cooperation example: An Empirical Case Study in Osaka Business Park

(1) work style that utilize a shared space

Building distributed workspace outside or the indoor of the building with less energy consumption, the work styles free to choose space depending on the preference of worker and comfort were realized. Also, by sending environment information and congestion level in real time to match the indoor or outdoor preference of the worker, the use of a variety of space to the worker was encouraged.

Thus, amount of moving to a distributed workspace is reduced the energy of the office room, but also workers for performing the activities even outdoors without staying office, the bustling of the city was created. (Figure 4)

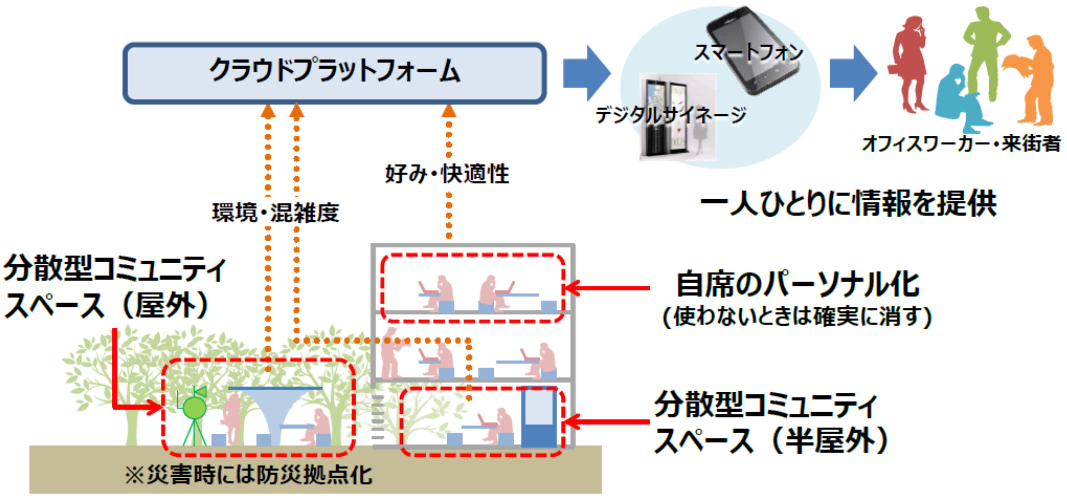


Figure 4 work style that utilizes a shared space

(2) Taking advantage of the EV in the region to demand response and BCP

For the realization of a low-carbon society, with a view to conversion to company's car to an electric vehicles (EV), and plug-in hybrid (PHV), we promote technology demonstration project of power supply system utilizing a battery of EV·PHV.

We have developed a new energy management system that leads to energy load control by EV·PHV and charging/discharging at the same time to EV·PHV, which are Japan's first five EV·PHV. (Figure 5)

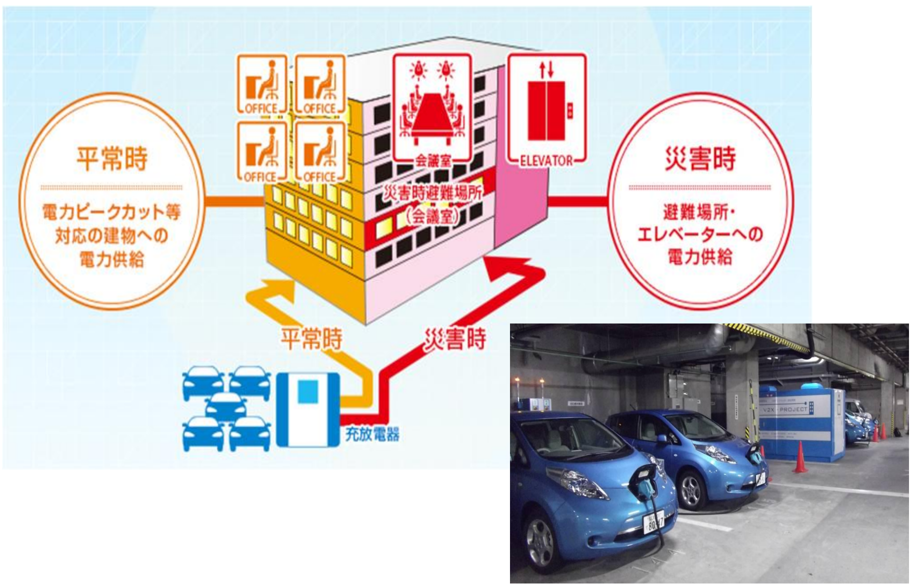


Figure 5, taking advantage of the EV in the region to demand response and BCP

4) three-dimensional urban Abeno-harukas [4]

"Abenobashi Terminal Building(Abeno-harukas)" is a building height of 300m that contains the stations and department stores, office, hotel, museum, observatory, such as a variety of applications, as shown in Figure 6. It aims to "energy-saving three-dimensional city", and various technologies have been applied.

Building Overview

Address Abeno-ku, Osaka Abenosuji 1-1-43

Applications Station, department stores, office, hotel, museum, observatory

Site area of approximately 28,700m^2

Total floor area of 353,000m^2

Height above ground 300m

Floor B5F · 60F · P1F

Structure steel reinforced concrete, steel frame

Owner Kintetsu Corporation

Design and supervision Takenaka Corporation

Construction Takenaka JV

外観<昼景>

Figure 6 building outline and appearance

(1) using the natural energy ventilation and lighting system: Eco-void

Void provided in the building each place, it becomes a light and for air passage, are in gently connecting the external and internal. (Figure 7)

VOID1 hotels Void

«Hotel daytime and night»

In the four seasons, it leads a comfortable outside of the air in the spring and autumn to Eco-void. Air that has passed through the void flows gently to the hotel hallway. Air in the void is deprived corridor heat, and is exhausted from the top.

VOID2 office Void

«Office daytime and night »

Comfortable outside of the air in the first half, gently flowing to the office, such as refresh corner through the void.

«Office night»

To introduce the night of cool air to the office, to cool the offices by night purge, to reduce the air conditioning energy for the next day.

VOID3 department store Void

«Department store daytime and night»

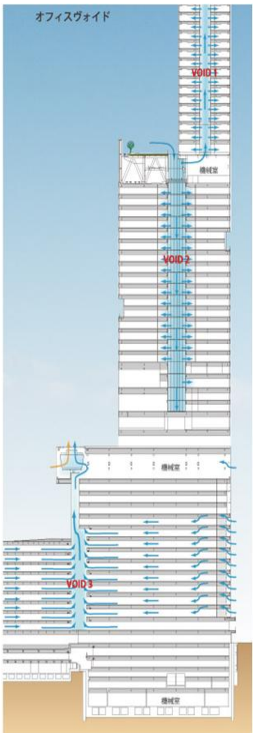
There are a lot of air, which is air conditioning in the department store where people gather many. Through the void without discarded as it is reused to cool the machine room.

«Department store night»

Department store cooling is required even in winter, in a night of cool air, cool the precursor enough by night purge, to reduce air conditioning energy for the next day.

(2) Comfort and energy saving and space by two glass: double skin

By the glass curtain wall for the outer wall of the building, a great view has spread. A double skin structure by the float laminated glass and Low-e double-glazed glass, we have adopted the air flow window system that does not leak the outside of the heat into the room. A high heat insulating shade is installed between the glass and the glass, thereby reducing the air conditioning load. (Figure 8)



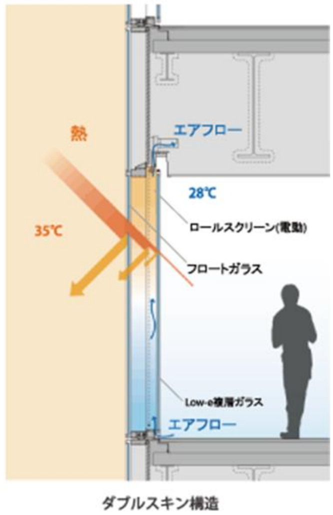


Figure 7 Eco-void

Figure 8 double-skin structure

(3) Power generation utilizing the garbage generated in the building: biogas power generation

From garbage such as department stores and hotels, a bio-gas as a fuel is produced. As well as reduce the amount of waste discharged outside of the building to 0, the generated biogas is used, such as in power generation and hot water as a fuel.

It was introduced a state-of-the-art energy-saving technology that make the biogas power generation by using the garbage generated in the hotel and department store restaurant, for the first time in high-rise buildings in Japan. (Figure 9)

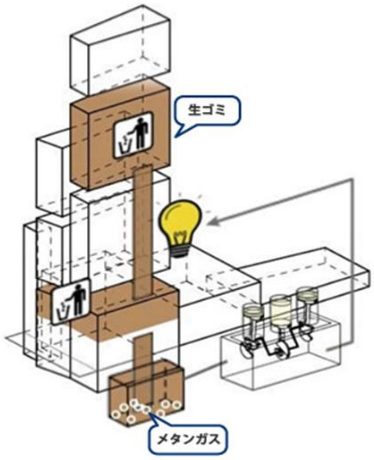


Figure 9 biogas power generation

(4) Energy saving in the comfortable office lighting: toning-dimming LED lighting

In Abeno-harukas Building, it is an important theme to be a comfortable for people while achieving energy saving. Depending on the season and time of day, it captures the natural light well, to illuminate gently with LED lighting (toning-dimming). In energy saving, in fact we are aiming to expand the pleasant "new comfortable area". (Figure 10)

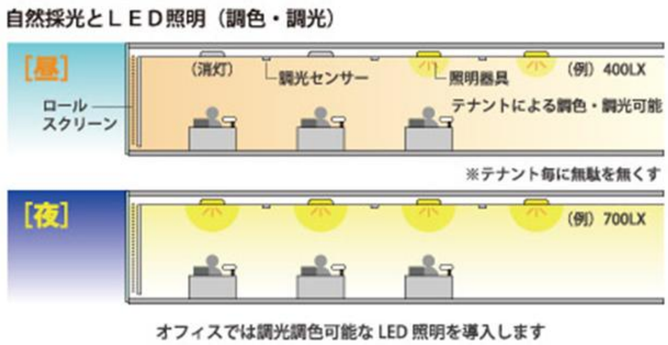


Figure 10 toning-dimming LED lighting

(5) High-efficiency energy system

By a combination of equipments with small environment load of high efficiency, we are building an energy system that can be friendly to the redundancy and safety relief and excellent maintainability in a space-saving. When there is a room and transportation benefits, we performs heat interchange to aged existing heat source. Others, a high-efficiency heat pumps which collect cooling exhaust heat and biogas generation equipment for heat recovery were installed. To reduce the valuable energy such as electricity and gas, we utilize natural energy, such as ambient air. (Figure 11)

(6) Energy saving promotion system by making the energy visible: A-EMS

In the case of motor vehicles, we check the speedometer, then operate the brake. Similarly, in the case of the building, there is a need for energy meter. The A-EMS, is a system making energy visible, and making everyone involved for performing management of participants. By interact with it, we are aiming to continue a reducing of CO_2 activities and reducing waste of energy. (Figure 12)

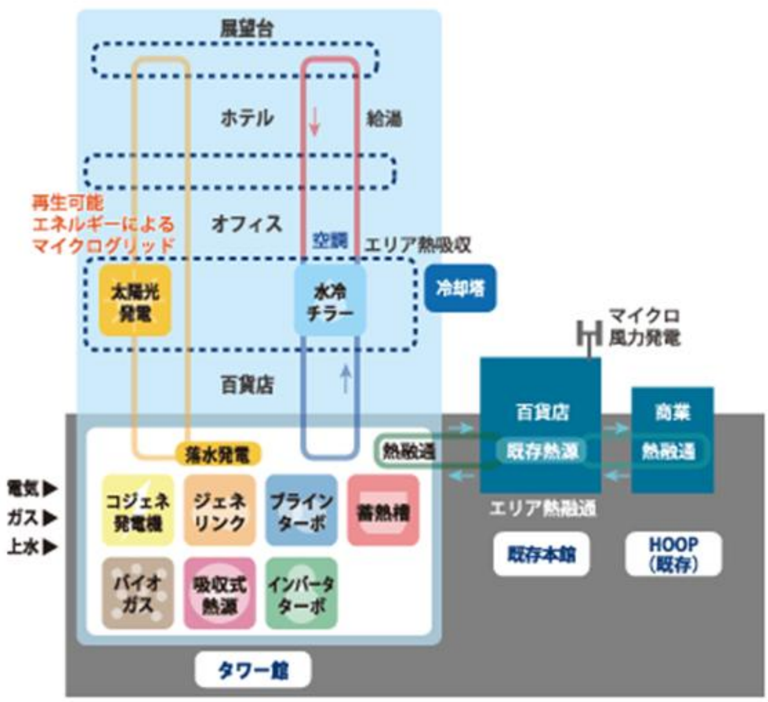


Figure 11 highly efficient energy system

Figure 12 A-EMS

(7) Leveling of energy load using the store-hours difference: peak cut

The hotel at night, the office on weekdays at day, department stores on holiday use a lot of energy. The leveling of energy load using business time difference, contributing to energy conservation. (Figure 13)

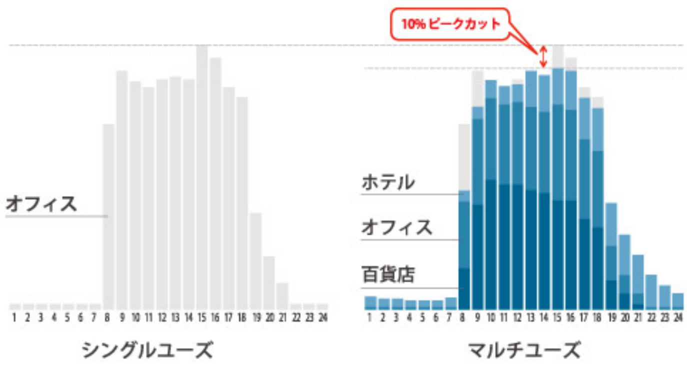


Figure 13 Leveling of energy load

(8) The energy conservation by heat exchange between applications: area heat recovery

Because a lot of people gather in the department store, cooling is required throughout the year. The exhaust heat for the cooling has also used for hot water supply of hotel rooms. The efficiency of energy by the exchange of heat between the area, contributing to energy conservation. (Figure 14)

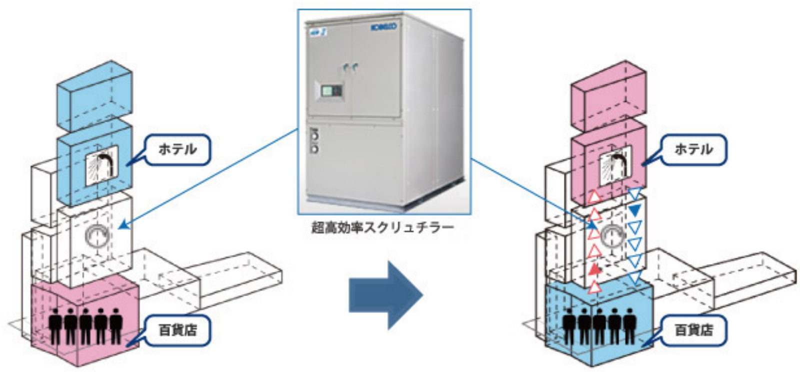


Figure 14　Area heat recovery

5) Summary

For smart communities, various initiatives are mentioned, demonstrated cases have also been reported. Here, we introduced the "Abenobashi Terminal Building

(Abeno-harukas)", as a demonstration cases and building cases in Osaka Business Park. In order to be inclusive green ILC of not only laboratory equipment and facilities, but around the facility, even in the ILC of the campus building and town planning, these systems and the technology might be made to the reference.

Reference
[1] http://www.enecho.meti.go.jp/category/others/basic_plan/pdf/140411.pdf
[2] http://www.meti.go.jp/policy/energy_environment/smart_community/doc/smartcommu.pdf
[3] http://lcdev.kek.jp/LCoffice/OfficeAdmin/Test/images/KEK_Report2013_5.pdf
[4] http://www.abeno.project-takenaka.com/