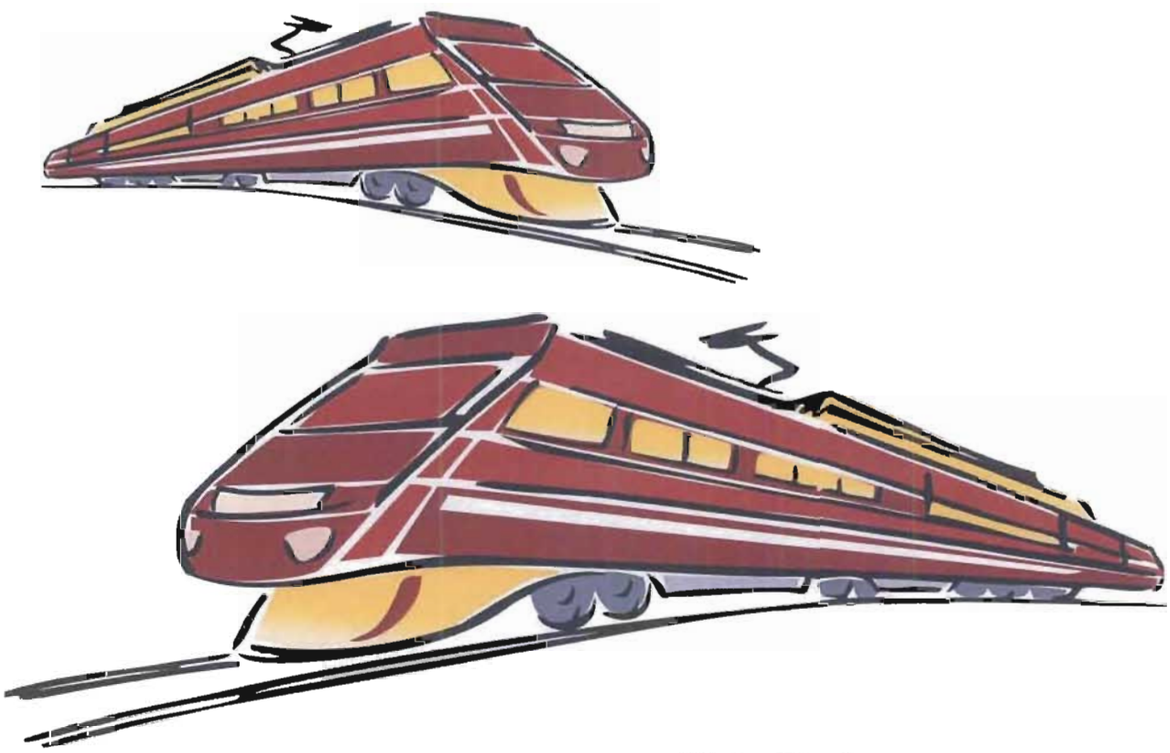


IMPROVING
THE
ENERGY EFFICIENCY
OF THE
RAILWAY SYSTEM

The
BEST
of
Railenergy

www.railenergy.eu

About Brochure



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Railenergy

The Best of Railenergy

The RAILENERGY project, targeted to increase energy efficiency of integrated railway systems by investigating and validating solutions ranging from the introduction of innovative traction technologies, components and layouts to the development of rolling stock, operation and infrastructure management strategies, provides its final results with this brochure.

Technical solutions for cutting energy consumption in railway systems are provided, thereby reducing both life cycle cost and CO_2 emissions at the same time. The set target was an overall 6% energy consumption reduction of rail systems by 2020.

Railenergy Target 2020



Efficiency potentials for each subsystem up to 30% by Railenergy (baseline 2005)

Railenergy system wide savings: 20 – 25% (specific energy)

Assumption: 25% deployment in Europe by 2020

Railenergy target 2020:
6% across Europe

The final outcome of the Railenergy project confirms that an average relative energy savings of more than 7 % can be reached. For the details please read through the Railenergy brochure.

How to measure & analyse energy in railway systems?

- Common simulation methodology
- First UIC/UNIFE TecRec (100_001)

How to compare & prioritise different measures?

- Cost-benefit & effectiveness
- Railenergy calculator
- Market readiness

How to define, browse & collect energy data?

- RAILENERGY KPIs
- Energy & CO_2 database



How to save energy costs?

- LCC screening
- In/out of service view

How to benchmark energy performance?

- RAILENERGY performance baseline
- Ranking of saving potentials
- Technology Assessment Reports

How to plan strategically your fleet procurement & refurbishment?

- Strategic Assessment Reports
- Practical check lists for professionals

The Railenergy knowledge base is a structured collection of all relevant results of the Railenergy project covering the results of the technical sub-projects as well as the results of the sub-project on energy efficiency management and including all results generated during the integration process, such as, economic and strategic assessment of energy efficiency technologies.

The Railenergy Website is the easy to access and easy to use online version of the Railenergy knowledge base (www.railenergy.eu). The website also includes the online version of the Railenergy Calculator. The architecture of the website is in accordance with the structure of the knowledge base. It consists of 5 main parts:

1. Introduction

The introduction guides the user through the main topics covered in the Railenergy Knowledge Base (website):

- Measuring & analysing energy in railway systems - Railenergy Methodology
- Defining, browsing & collecting energy data - Key Performance Indicators

- Benchmarking energy performance - UIC/UNIFE TecRec (100_001)
- Comparing & prioritising different energy saving measures - Technology Assessment Reports
- Check possible energy cost savings - Railenergy Calculator
- Strategically planning the fleet procurement & refurbishment - Technology Recommendations

2. Railenergy methodology

In the Methodology section the complete background on the methodologies behind the technology simulations is described:

- The Technical Simulations of railway energy consumption on system level and their scope;
- The Demonstration Scenes and Use Cases which ones been chosen in the project;
- A detailed definition of Key Performance Indicators and their calculation (as outputs of the technical simulations);
- The rationales behind the economic evaluation.

3. Recommendations

Here the results of the detailed strategic evaluation of the technologies and operational measures are shown. The main messages in terms of recommendations for the different energy supply types and service types are presented here, namely for DC, AC and Diesel energy supply and for sub-urban, regional, inter-city, high speed and freight mainline rail services.

4. Technology Descriptions

This section contains the general descriptions of the technologies and operational measures developed and assessed within Railenergy.

5. Railenergy Calculator

Railenergy Calculator is a web-based calculator developed within Railenergy using the technical, economic and strategic results of the project. It is designed to support management decisions regarding the implementation of new technologies or operational measures in terms of their energy, CO_2 and economic performance.

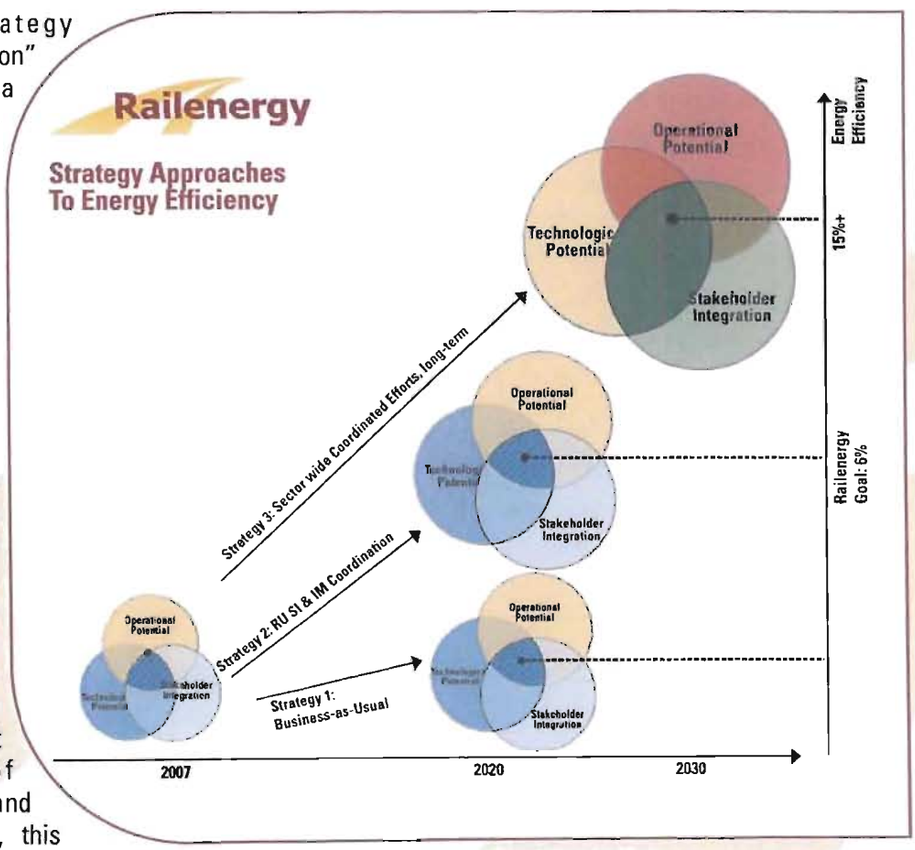
The calculator incorporates the main results of the Railenergy project and makes them available and usable to potential, interested users. Information and data from the technology developing sub-projects feeds into the calculations of energy saving potentials coming from technologies and operational measures. This information is connected to other operational and economic data to give a result on potential overall energy (and CO_2) savings as well as expected impacts on investment costs.

The RAILENERGY Vision on Energy Saving Potentials

Railenergy's vision is a step-by-step approach towards a modern, energy efficient railway system including rolling stock and infrastructure and their interfaces, taking well into account the historically developed limitations and restrictions (different catenary systems, gauge, rail-wheel etc.).

Even for the "Business-as-usual" strategy characterised by mainly independent implementation of technical and operational efficiency measures, the average energy efficiency improves until 2020. But due to a lack of coordination on the one hand and little focus on systemic optimisation on the other, the efficiency gains are small and large potentials remain unexploited.

The "Coordinated Efficiency Efforts" strategy can be described as a common approach by three of the main stakeholders of the project - the railway undertakings, infrastructure managers and system integrators - to increase energy efficiency in a coordinated effort. This effort focuses on simultaneously improving technological and operational performance and therefore allowing for the exploitation of a larger efficiency potential until 2020 (6%). Railenergy can be seen as a pilot project for the implementation of this energy efficiency strategy.



The long-term strategy "Sector-wide Integration" is distinguished by a harmonised and sector-wide approach to energy efficiency where the strategies and actions of all relevant stakeholders - including the railway undertakings, infrastructure managers and system integrators as well as European, national and regional regulative bodies and energy suppliers - are coordinated and integrated. In addition to optimising energy efficiency on the system level by joint implementation of innovative technical and operational measures, this proactive strategy aims at systematically removing barriers and improving political, institutional and contractual framework conditions and thus allowing for the optimum exploitation of efficiency potentials.

Reaching the target

Railenergy set the target to reduce by 6% the specific energy consumption of the rail system by 2020 by addressing different systems, subsystems and components of the railways with a holistic approach.

During the course of the project, Railenergy has investigated the most promising solutions suitable for improving the energy performance of railway operation, trackside equipment, onboard traction, components and auxiliaries. Once the development phase has been completed, a specific methodology to assess the potential overall savings has been drawn, which is shown in the following picture.



The approach is structured in a sequence of steps from the establishment of a clear baseline for comparison, to the estimation of future savings, tuned through the deployment expectations. This has been achieved by combining together figures like the railway production in the different European countries (EU, Norway and Switzerland), current consumptions baselines, expected savings per technology application or use of good practices.

The baseline of the calculation is the definition of the Railway production and the specific consumption per country, structured per service type and energy supply type.

The estimated energy savings for each technology has been developed in the scope of Railenergy; in those tables, the percentage of savings of each technology is reported for each service type and power supply.

In order to adhere to the business perspective while calculating the estimated overall savings, the deployment of the combinations of Railenergy solutions in the different countries has been envisioned accordingly with three different scenarios, as mentioned above:

- "Business as usual"
- "Additional effort"
- "Additional effort long-term"

For each country, a specific scenario has been selected; then the relative and absolute savings have been calculated. As the project target shall be reached globally at the European level, the total savings has been calculated by adding the absolute values of savings of each single country. Said absolute value is then compared with the baseline in order to determine the overall percentage of energy efficiency gain that is achieved.

Based on the first calculations of savings from technologies and operational measures, it seems plausible to achieve at least 6% of energy savings throughout the entire European railway system. In particular, by using the above described scenarios, with specific exploitation rates, an average relative energy savings of more than 7% can be reached.

Contribution to European Standardisation

One of the most important Railenergy outcomes is the contribution to the European standardisation, for instances the elaboration of joint UIC/UNIFE Technical Recommendations. A Technical Recommendation (TecRec) is a joint UIC/UNIFE standard of which the primary field of application is the European railway transportation sector covering all interfaces and subsystems from vehicle to track.

TecRec 100_001 "Specification and verification of energy consumption for railway rolling stock"

The Technical Recommendation 100_001 is applicable for the specification and verification of energy consumption of railway rolling stock. The criterion for the energy consumption of rolling stock is the total net energy consumed – either via the rail pantograph or from the fuel tank – over a predefined service profile, which is either taken from the future operation of the train, or according to a standardised typical profile valid for the specific service category of trains. This method secures directly comparable results by and representing the real operation of a train.

The general purpose of this Technical Recommendation is to provide a comparative framework to evaluate energy performance values for train sets or locomotives on a common basis, thereby benchmarking and improving the energy efficiency of all types of rail vehicles. This recommendation is not suitable for comparison with other modes of transportation or for comparison between diesel and electric traction - as it only deals with the energy consumption of the vehicle itself.

TecRec 100_001 will be transformed into a CENELEC Technical Specification (TS) at the end of 2011.

Draft TecRec 400_001

"Technical Specification for reversible DC substations"

The second Technical Recommendation developed is currently under revision with its publication foreseen end of 2011. The standard will cover a complete set of functional requirements for 1.500V and 3.000V traction converters for an improved recovery of braking energy in DC traction systems by reversible DC substations.

Railenergy Calculator

The Railenergy calculator is a web-based decision support tool for the European rail industry to align energy calculations, methodology and increase common understanding sector-wide. It is first of all a business-to-business screening tool for R&D, procurement and upgrade projects.

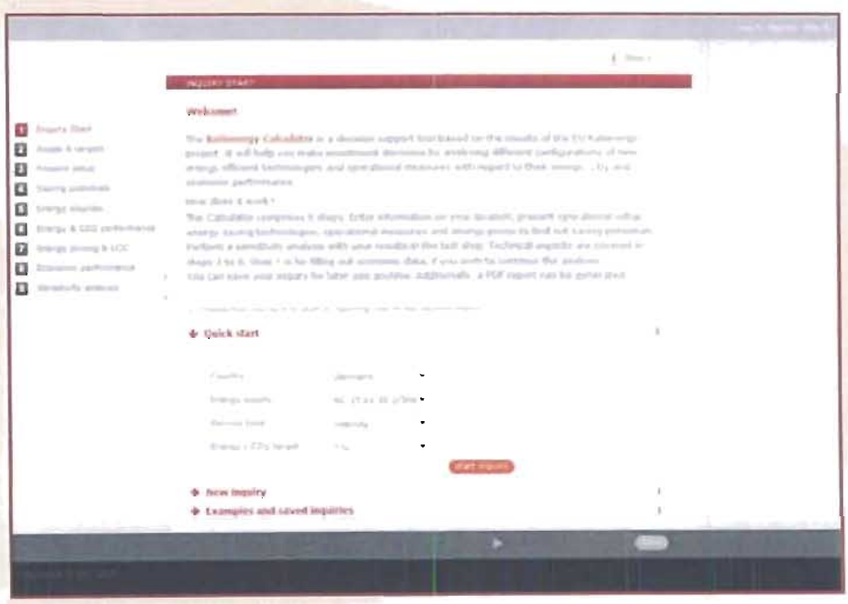
The tool performs analysis and prediction of energy savings, CO_2 emissions and simplified life cycle costs. The Railenergy Calculator is NOT a comparison tool between transport modes.
The Railenergy Calculator is most appropriate in the first phases where the partners typically need better clarification of realistic potentials without investing too much time.

The tool has been programmed to really meet the user wherever the user is. There are nine steps to go through and the principle is like ordering a trip or a hotel on the internet. This sentence is unclear. Suggestion: Normally, logic suggests a user start from the beginning, but the program is capable of handling a user who starts wherever possible and advises the user on how to complete the necessary data.

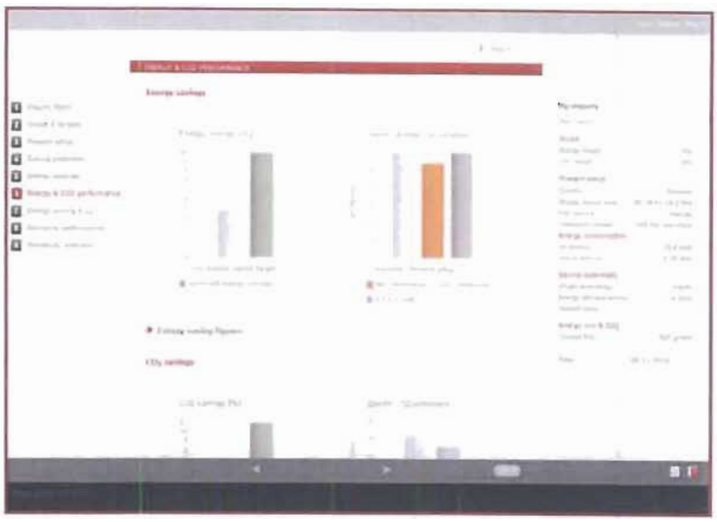
Below is the diagram for the Calculator, which is clearly marked in three parts:

Part A: Technical assessment
Part B: Economic assessment
Part C: Sensitivity analysis

The tool is available on the front page of the project website www.railenergy.eu



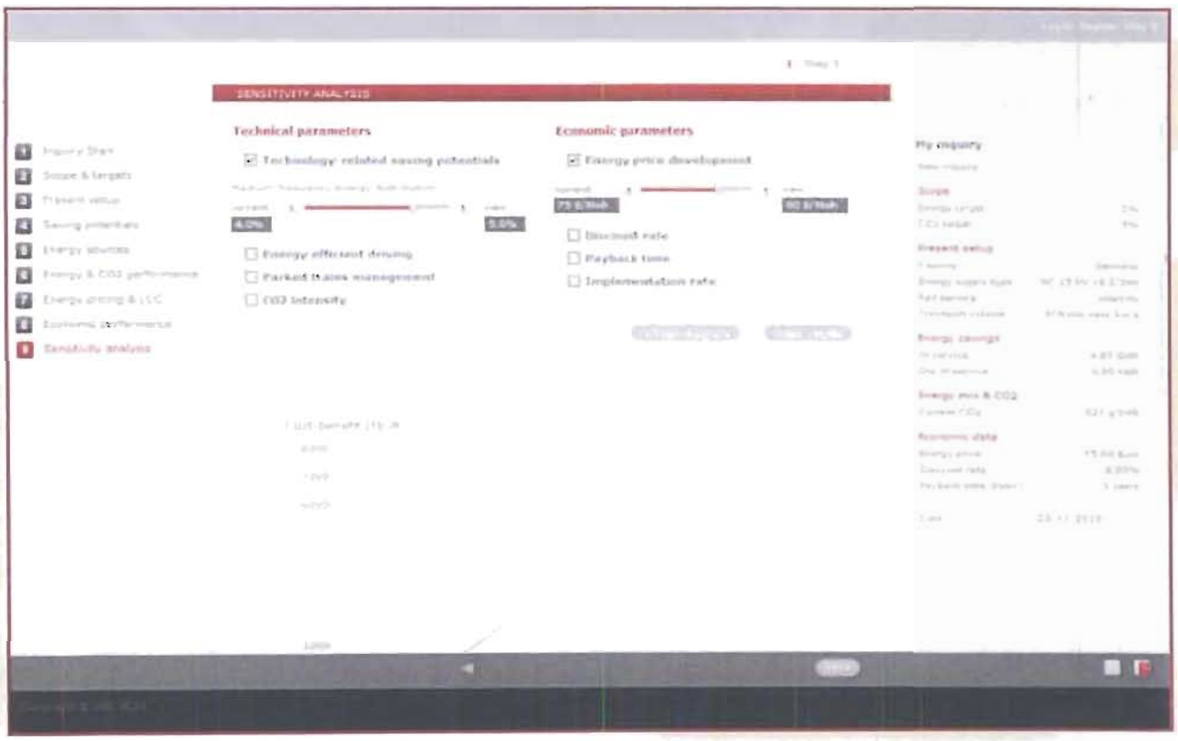
The tool will help the system integrators in assessing technologies to be used in future competitive rail vehicles and infrastructure components. Likewise, railway operators and infrastructure managers will benefit by being able to evaluate the operational, technical and strategic investment opportunities for energy efficiency solutions within procurement, leasing, operation and maintenance of railway systems.



Extract of technical results from the tool:

The strategic evaluation is based on a simplified cost benefit/ cost effectiveness methodology including a strong lifecycle perspective. The tool will enable the definition of the optimal mix of energy efficiency strategies at either vehicle or network level, with respect to both energy efficiency and costs (e.g. investments, payback time) regarding both possible techniques but also the uncertainty in the planning process (future traffic) and tariffs.

Extract of economic results (with sensitivity analysis) from the tool:



Recommendations

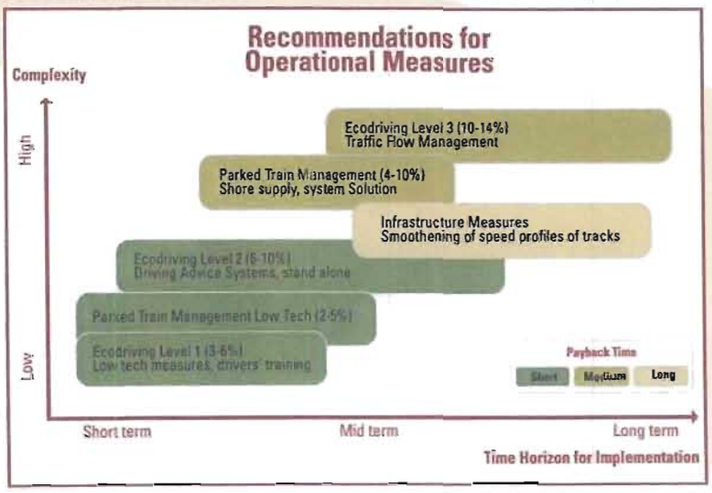
The Railenergy recommendations have been developed and applied throughout the entire project. The recommendations are built on an approach which consists of three levels: a technical level, an operational level and finally an economic/strategic level. Collected data has been simulated, calculated and evaluated to finally be assessed strategically.

In the project 5 specific service types and 3 energy supply types (DC, AC, high-speed, and diesel) were investigated. For the detailed recommendations please see the description of each assessment.

Operational measures

Operational measures – in-service as well as out-of-service – are considered as low hanging fruits since high savings at relatively low costs can be achieved. The operational measures are relevant for each recommendation described below. In order to avoid duplication, a summary of the operational measures can be seen here:

- Eco-driving (levels 1 and 2) is highly promising. It has a saving potential between 5% and 15% depending on the actual operational regime and on the level of sophistication of the introduced system.
- Energy efficient traffic management (eco-driving level 3) will allow significant reductions in energy consumption in the railway system (between 10% and 20%). The implementation of such systems requires a high degree of cooperation between the different stakeholders - infrastructure managers, train operating companies, rolling stock and signalling equipment manufacturers and standardisation bodies and safety authorities. The needed joint effort goes clearly beyond the "business as usual" scenario. A reasonable degree of standardisation is needed in order to guarantee swift progress in this field.
- Parked train management is a very promising operational measure with a high saving potential (4%-8%) and comparably low investment costs. It mainly focuses on a more efficient load and temperature management for parked trains and can be realized at a first stage by low-tech measures. More complex systemic solutions require higher investments and a higher organisational effort because established processes and habits have to be changed.



DC power supply systems for all types of operation (suburban, regional, intercity, freight)

Operational

To receive a complete overview on the benefits of the operational measure please read the chapter "Operational measures" (page 11).

Energy optimised driving ("eco-driving") is highly promising, like for the other types of power supply (AC, DC). Keep in mind that the priorities for the driver are not the same as in AC systems (since regenerative braking is not always possible in DC), but similar to Diesel trains.
An adequate load and temperature management for parked trains is essential.

Overall, energy efficient traffic management will allow significant reductions in energy consumption, as well as for AC and Diesel propulsion. Such systems are the only significant development which are clearly beyond "business as usual", i.e. such a development, and mainly its introduction into real rail operation, will require joint efforts by infrastructure and train operating companies, rolling stock and signalling equipment manufacturers as well as standardisation bodies and safety authorities. A reasonable degree of standardisation (not too low but not too high) will have to be found to create a way forward with this respect.

Rolling stock

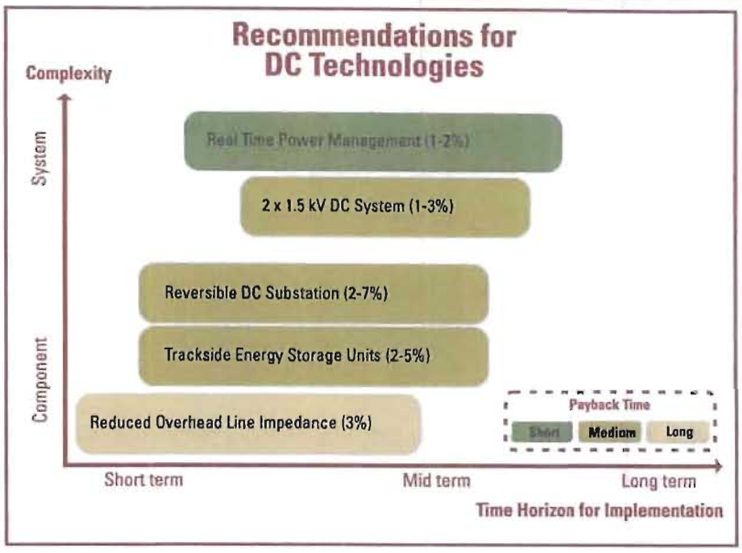
Some interesting technologies can be applied during refits for existing rolling stock, e.g. optimum motor and converter control (flux control, PWM patterns, auxiliaries). This can often be done by software, sometimes with minor changes in the hardware (e.g. additional contactors). Many of these changes are highly profitable and have short payback times, hence can be applied also to rolling stock with limited life time expectation.

Infrastructure

Consequently, integrate costs for energy losses in substations and the catenary system into life cycle cost (LCC) calculations for any change to the DC power supply systems.
Corresponding results will influence the optimum design of wire cross sections and selection of materials ("reduced line impedance").

The integration of reversible substations and / or trackside energy storage units shall be considered for networks with medium traffic density. Their economical evaluation can only be made for individual cases, under precise consideration of network topology, catenary system impedances as well as rolling stock (train mass, speed) and operations (timetable). A combination of measures may result in an optimum (e.g. strengthening the catenary system by additional feeders, plus one reversible substation in an ideal location).

Special systems, like the 2 x 1.5-kV DC system, may be of interest only for an increase in capacity of the power supply system (upgrade of existing systems when traffic is increased). They are always in competition with additional substations and / or lowering catenary impedances. The profitability of the 2 x 1.5-kV DC system must be carefully evaluated against these other solutions, and energy savings are more an interesting side effect than the reason for such investments.



AC power supply systems for all types of operation (suburban, regional, intercity, freight)

Operational

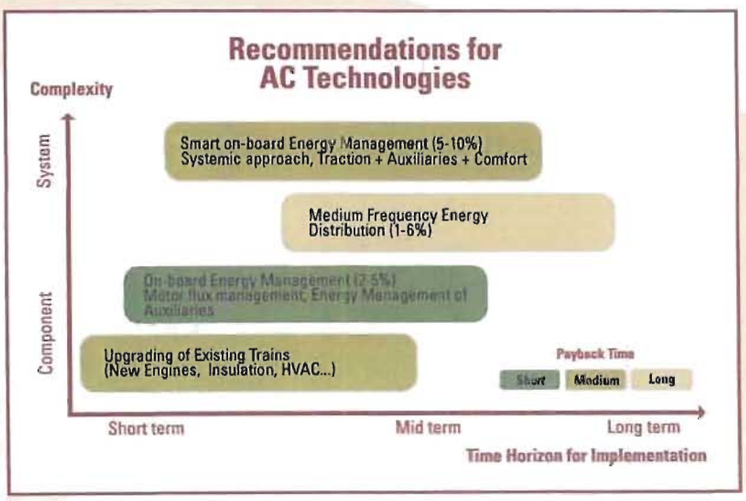
To receive a complete overview on the benefits of the operational measure please read the chapter "Operational measures" (page 11).

Rolling stock

Motor flux management is a very promising efficiency technology with a savings potential at system level between 2% and 4%. Since it can be mostly done by software changes only or by minor hardware changes, it is very profitable and has a low payback time.

Equally promising is the energy management of auxiliaries (MV load management). Investment costs and complexity of changes are comparably low, resulting in short payback times. Savings potential is between 2 and 6%.

Medium frequency energy distribution is an interesting technology to follow. It has an energy saving potential between 1% and 6%.



Most of the promising efficiency technologies mentioned above can also be applied during refits for existing rolling stock. Examples are motor flux management and management of auxiliaries. Since they are highly profitable and have short payback times, they can also be applied to rolling stock with a shorter remaining lifetime.

The following figure gives an overview over the qualitative dependence of level of complexity and pay-back time for promising AC efficiency technologies:

Infrastructure

Since AC systems and especially the modern 25kV systems are already energy efficient, the improvement options are rather limited. Because of relatively high effort and investment costs for infrastructure measures, payback times would be far too long if the measures would be implemented for energy efficiency reasons only.

Nevertheless, it makes sense to include potential energy savings in the LCC assessment of upgrading measures for the catenary or for the dimensioning of new AC supply systems. Under specific conditions the reduction of the overhead line impedance by means of additional wires, bigger cross sections or alternative materials can pay off in the long run if a higher capacity of the line is either actually needed or at least anticipated in the near future.

AC power supply systems for High-Speed service

Operational

The recommendations for high-speed operation would fall into two parts for "in service" operation: one is similar to AC conventional report for the operation taking place on conventional lines with mixed traffic; the other one is for operation on dedicated high-speed lines. Finally, the "out-of-service" mode recommendations are similar to the ones made for AC conventional (page 11).

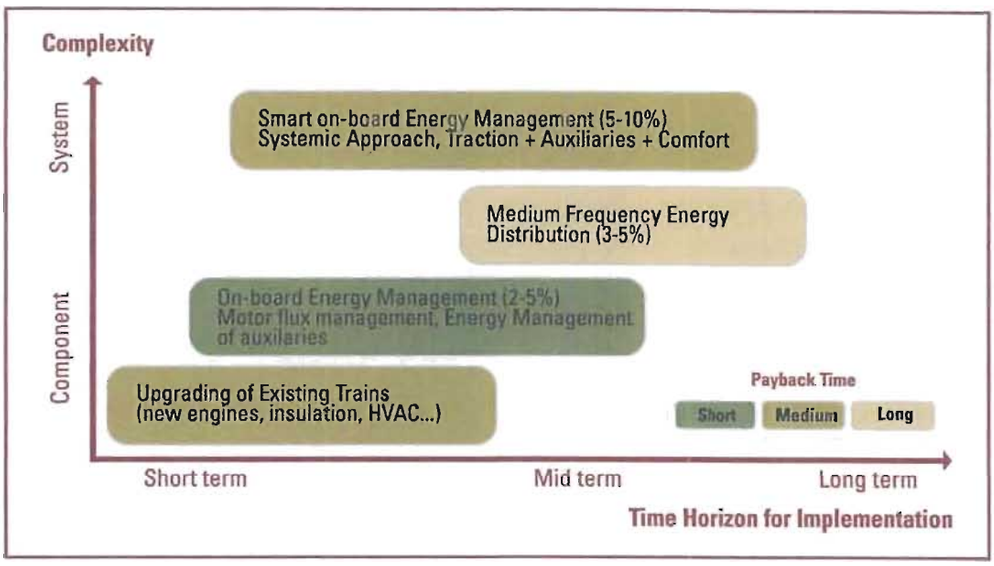
Rolling stock

For older generation high-speed train sets motor flux management is a very promising efficiency technology with a savings potential at system level between 2% and 4%. Since it can be done mostly by software changes only or by minor hardware changes, it is very profitable and has a low payback time.

Equally promising for such older train sets is the energy management of auxiliaries (MV load management). Investment costs and complexity of changes are comparably low resulting in short payback times. Savings potential is between 2 and 6%. Since both motor flux and MV load management are highly profitable and have

short payback times, they can also be applied to rolling stock with a shorter remaining lifetime.
Medium frequency energy distribution is an interesting technology to follow for new AC high-speed rolling stock. It has an energy saving potential between 3% and 5%.

The following figure gives an overview over the qualitative dependence of level of complexity and pay-back time for promising HS efficiency technologies:



Infrastructure

Since AC systems and especially the modern 25kV systems are already energy efficient, the improvement options are rather limited. Because of relatively high effort and investment costs for infrastructure measures, payback times would be far too long, if the measures would be implemented for energy efficiency reasons only.

Nevertheless, it makes sense to include potential energy savings in the LCC assessment of upgrading measures for the catenary or for the dimensioning of new AC supply systems. Under specific conditions the reduction of the overhead line impedance by means of additional wires, bigger cross sections or alternative materials can pay off in the long-run if a higher capacity of the line is either actually needed or at least anticipated in the near future.

The integration of reversible substations and/or trackside energy storage units shall be considered for networks with medium traffic density but it is unlikely to play a role for the remaining DC 3kV high-speed networks.

Diesel loco and DMU (Regional, Intercity and freight service)

For Diesel Multiple Units and Diesel locos the recommendations are focussed only on operation and rolling stock.

Operational

To receive a complete overview on the benefits of the operational measure please read the chapter "Operational measures" (page 11).

Rolling stock

Motor flux management is a very promising efficiency technology with a savings potential at system level between 2% and 4%. Since it can be done mostly by software changes only or by minor hardware changes, it is very profitable and has a low payback time.

To implement an on-board energy storage system in a D/EMU is a very promising solution. The system's innovative ultracapacitors store the energy released each time a vehicle brakes and reuse it during acceleration or operation. It boosts a vehicle's performance by adding extra power during acceleration. This highly successful solution saves up to 35% in multiple diesel units. This, in turn, reduces emissions and costs.

The Permanent Magnet motor technology improves overall vehicle optimization, increases motor efficiency and reduces motor volume and weight; compared to inductor motors of the same size, this compact and powerful PM motor system: using less energy, facilitates motor cooling, improves motor performance and reduces vehicle life-cycle cost. The savings potential is up to 4% and can be used for D/EMU and Diesel electric locos.

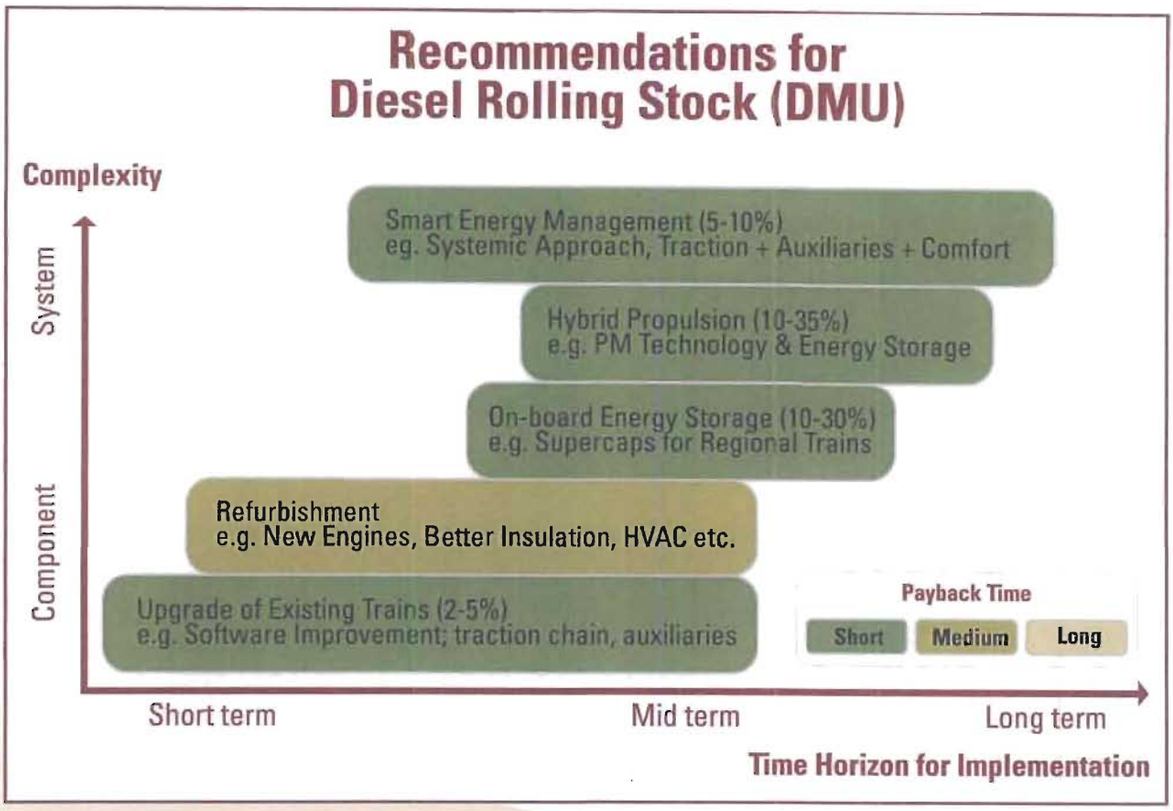
A combination of on-board energy storage with PM technology increases the savings potential and is a very promising approach for energy saving.

To use the waste of the cooling circuit of the diesel engine for heating is a proven technical solution and already state-of-the-art in DMUs. Up to 3% of the fuel consumption can be saved.

Equally promising is the energy management of auxiliaries (MV load management). Investment costs and complexity of changes are comparably low, resulting in short payback times. The savings potential is between 2 and 6%.

Medium frequency energy distribution is an interesting technology to follow. It has an energy saving potential between 1% and 6%.

Most of the promising efficiency technologies mentioned above can also be applied during refits for existing rolling stock. Examples are motor flux management and management of auxiliaries. Since they are highly profitable and have short payback times, they can be also applied to rolling stock with a shorter remaining lifetime.



Conclusions

Railenergy was a pioneer in and of itself. The project was launched when the energy topic was not on the top of the political agenda. However, the project was nearly finished when the subject became a priority at the political, economical and technical levels. It can be said that the result of the project and the content of this final brochure is definitely well spotted.

The Railenergy project has greatly contributed to energy conservation research in railway applications and has shined a spotlight on the tremendous advantages, both in terms of environmental impact and costs, which the railway sector can now exploit to further its objective of sustainable mobility. The objective of the Railenergy project was to reduce overall energy consumption by 6%. To place this into context, the annual energy bill of SNCF and DB is approximately €2 bn; therefore, with the application of the discoveries made throughout the Railenergy project, these companies stand to save €6 mn that can then be reinvested into new technologies, improved infrastructure, or further research and development.

Railenergy was also at the forefrontin European Standardization. The first UIC/UNIFE Technical Recommendation is based on a Railenergy deliverable. CENELEC is about to transform the TecRec 100_001 into a CENELEC Technical Specification (TS) at the end of 2011

Although the goals set out at the beginning of this project have been achieved, the consortium cannot emphasize enough the benefits that reduction in energy consumption bring to both the suppliers and users of rail products; while Railenergy may have finished its objectives, we hope to see a continued effort, both on a European and global level, to further promote and encourage smarter technologies and improved conservation efforts.

After these challenging 4 years, the project came to an end. This brochure summarises the Railenergy recommendations and the different technologies investigated in the project. However, it is very difficult to describe the team work which is behind these lines. As the coordinator of the project, I would like to thank to all experts who contributed to the project's results for their continuous support and for the positive team spirit which evolved during these years.



Energy saving components & measures

I. Energy Efficient Train Operation (EETROP)

Technology description

The concept of Energy Efficient Train Operation comprises the saving of energy and other resources through better planning and handling of train operations. Introducing energy efficiency and power management into timetabling, as well as real-time operations enables timetable planners, dispatchers and drivers to manage their traffic in the most efficient manner whilst fully respecting the underlying mandatory conditions such as punctuality, capacity, etc.

The phases and proposed tools are:

- EETROP Planner Timetabling
- EETROP Manager Power and tariff management
- EETROP Dispatcher Real-time planning of traffic
- EETROP Driver Onboard driving advice

Energy saving potential

Eco-driving Level 1: Driver training					
	Service type				
Energy supply typZe	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	2-6%	2-6%	2-6%	Not applicable	2-6%
DC 3 kV	2-6%	2-6%	2-6%	2-6%	2-6%
AC 15 kV 16,7 Hz	2-6%	2-6%	2-6%	2-6%	2-6%
AC 25 kV 50 Hz	2-6%	2-6%	2-6%	2-6%	2-6%
Diesel	Not applicable	2-6%	2-6%	Not applicable	2-6%
Technology notes	Eco-driving level 1 is based on training of drivers and with no technical drivers advice systems. By applying eco-driving railways want to enable their less experienced drivers to perform like experienced drivers. The potentials refer to the "in-service" mode energy consumption only and not the total. The ranges are quite large due to the different baselines and actual implementation of the training.				
Baseline technology	Normal driving is not one single value but covers a range of drivers' behaviour. The baseline is therefore estimated as the average performance with no eco-driving training and given the normal operational conditions including traffic and weather incidents. This does not mean that some drivers do not drive energy-efficiently.				

Eco-driving Level 2: Onboard device					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	6-10%	6-10%	6-10%	Not applicable	6-10%
DC 3 kV	6-10%	6-10%	6-10%	6-10%	6-10%
AC 15 kV 16,7 Hz	6-10%	6-10%	6-10%	6-10%	6-10%
AC 25 kV 50 Hz	6-10%	6-10%	6-10%	6-10%	6-10%
Diesel	Not applicable	6-10%	6-10%	Not applicable	6-10%
Technology notes	Onboard drive advice systems are already in use several places in Europe. The technology is build on display for the driver based on continuous or stepwise calculations according to a defined algorithm placed in a device. Level 2 could be done with or without much training (rather instructions) but the values include level 1. The potentials refer to the "in-service" mode energy consumption only and not the total. The ranges are quite large due to the different baselines and actual implementation of the training.				
Baseline technology	Normal driving is not one single value but covers a range of drivers' behaviour. The baseline is therefore estimated as the average performance with no eco-driving (training or device) and given the normal operational conditions including traffic and weather incidents. This does not mean that some drivers do not drive very energy-efficiently.				

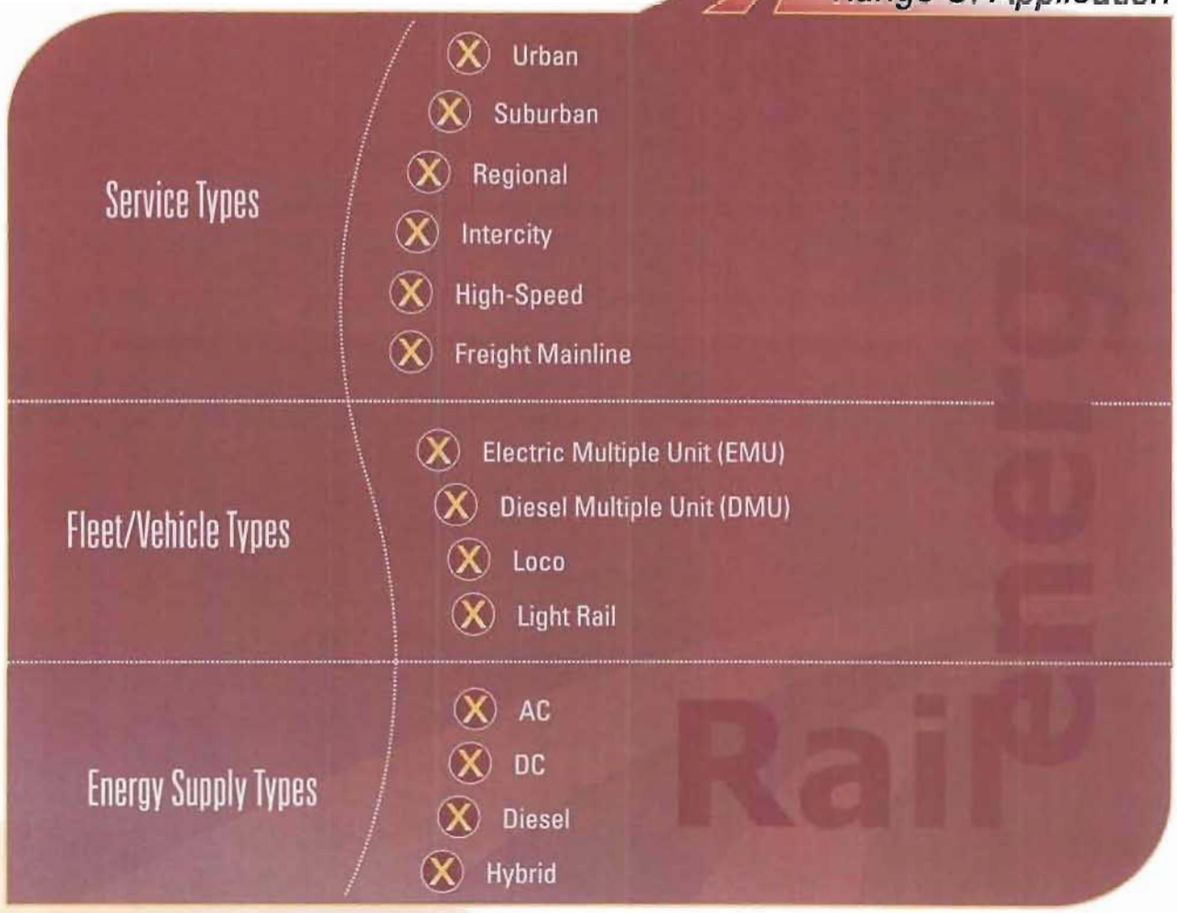
Eco-driving Level 3: Fluid traffic management					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	10-14%	10-14%	10-14%	Not applicable	10-14%
DC 3 kV	10-14%	10-14%	10-14%	10-14%	10-14%
AC 15 kV 16,7 Hz	10-14%	10-14%	10-14%	10-14%	10-14%
AC 25 kV 50 Hz	10-14%	10-14%	10-14%	10-14%	10-14%
Diesel	Not applicable	10-14%	10-14%	Not applicable	10-14%
Technology notes	This approach has not yet been fully developed for implementation and deployment. The technology is based on optimisation of the network energy efficiency by prioritising single train runs (that will drive energy efficient using level 1 and 2)				
Baseline technology	Normal driving is not one value as there is no one single average drivers behaviour. In reality most railways want their eco-driving to enable less experienced drivers to perform like experienced drivers. The baseline is therefore a sort of average performance given the normal operational conditions including traffic and weather incidents.				

Advantages of the new technology

The main advantage of this very promising energy saving measure is the flexibility to choose between simple and advanced solutions depending on the needs and possibilities to involve other players than the train drivers (e.g. the dispatchers at the infrastructure manager).

The three eco-driving levels can be implemented for both diesel and electric traction. systems

Range Of Application

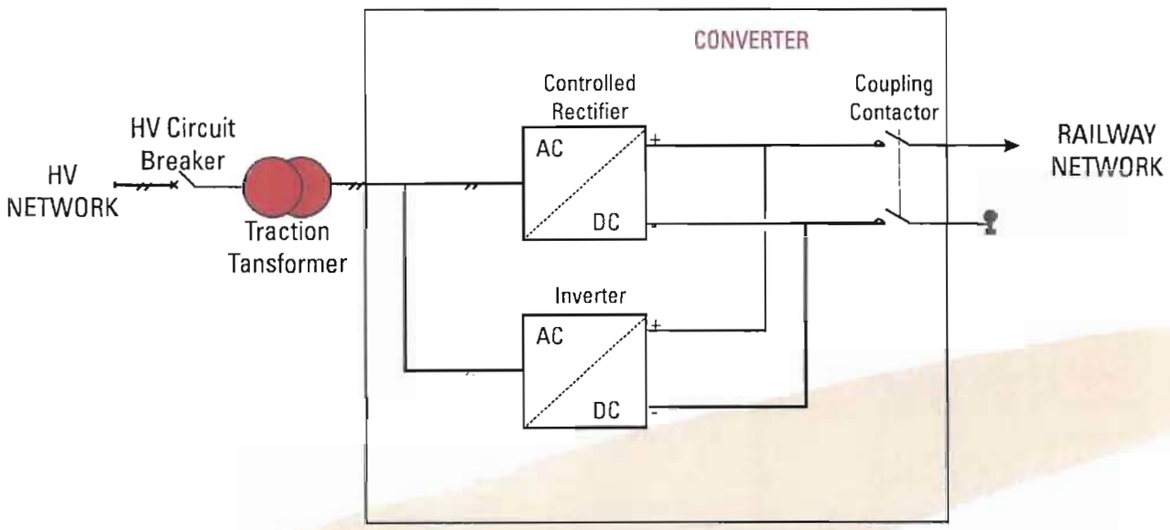


II. Reversible DC substation

Technology description

Reversible DC substations enable the recovery of almost all regenerative braking energy (99% of recoverable regenerative braking energy) into the upstream network, having given priority to natural exchange between trains. This is carried out by combining a controlled rectifier/inverter with a software control function to be able to recover braking energy between nominal voltage (U_n) and maximal voltage (U_{Max2}) according to EN 50163.

Advantages compared to existing technologies: the new technology offers maximum efficiency compared to parallel inverter or storage systems (flywheel and super capacitors) combined with a diode rectifier, enabling the removal of braking resistors onboard of traction units without transferring additional load to mechanical braking.

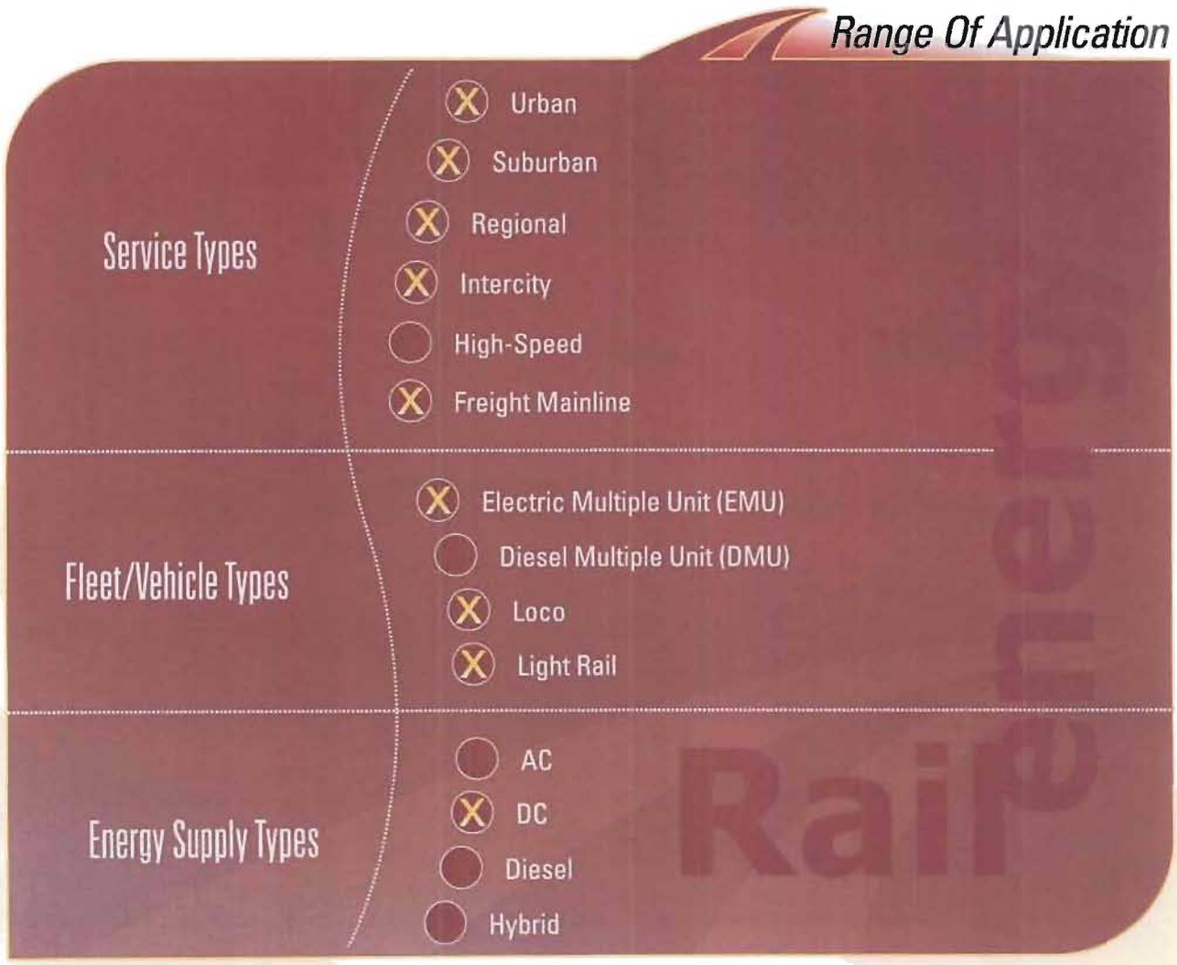


Energy saving potential

Reversible DC Substation					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	9-11%	6-8%	4-6%	Not applicable	0-3%
DC 3 kV	4-6%	3-5%	1-3%	0-2%	0-2%
Technology notes	This technology applies wherever:-The energy issued from dynamic braking is important, itself influenced by the frequency of stops, motor rate of trains, line gradients,-The natural receptivity of the line can be improved to near 100%, itself influenced by off-peak operational headways, small train auxiliaries power consumptions, reduced value of system line voltage or significant line losses				
Baseline technology	"Normal" DC sub-station with unidirectional DC substation with natural exchange of braking energy between regenerative trains (natural line receptivity) =Actual State of the art				

Advantages of the new technology

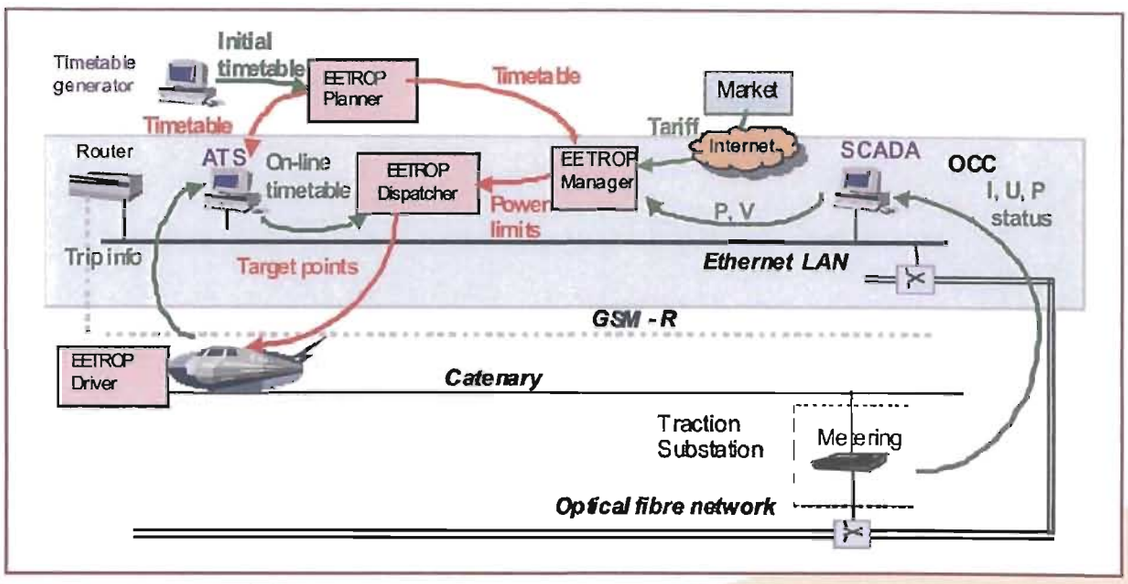
The main advantage of this new technology is that maximum energy-efficiency can be achieved as braking resistors are no longer used on traction units. This is a breakthrough. The recovered energy is available all along the line for commuter trains or at stop points when the distances between passenger stations are greater. The capacity for energy recovery using this new technology can be very large compared to storage systems. This criterion is very important for high gradient lines. With the exception of parallel inverters, other technologies cannot be used on all DC voltages (750, 1.500 V and 3.000 V). Furthermore, for each application, they should be rated in terms of power and energy, based on which one is more critical. In any case, return on investment can be achieved more easily using the new technology.



III. Real-time management

Technology description

Real-time management, transposed into Energy Efficient Train Operation (EETROP), includes the monitoring of the power feed in all substations, working with the power provider to compile a daily reference diagram featuring power needs, forecasting power requirements based on on-line timetables, optimising global energy demand and smoothing out the power demand curve, and finally, forwarding recommendations to Automatic Train Supervision (ATS) for economical driving.



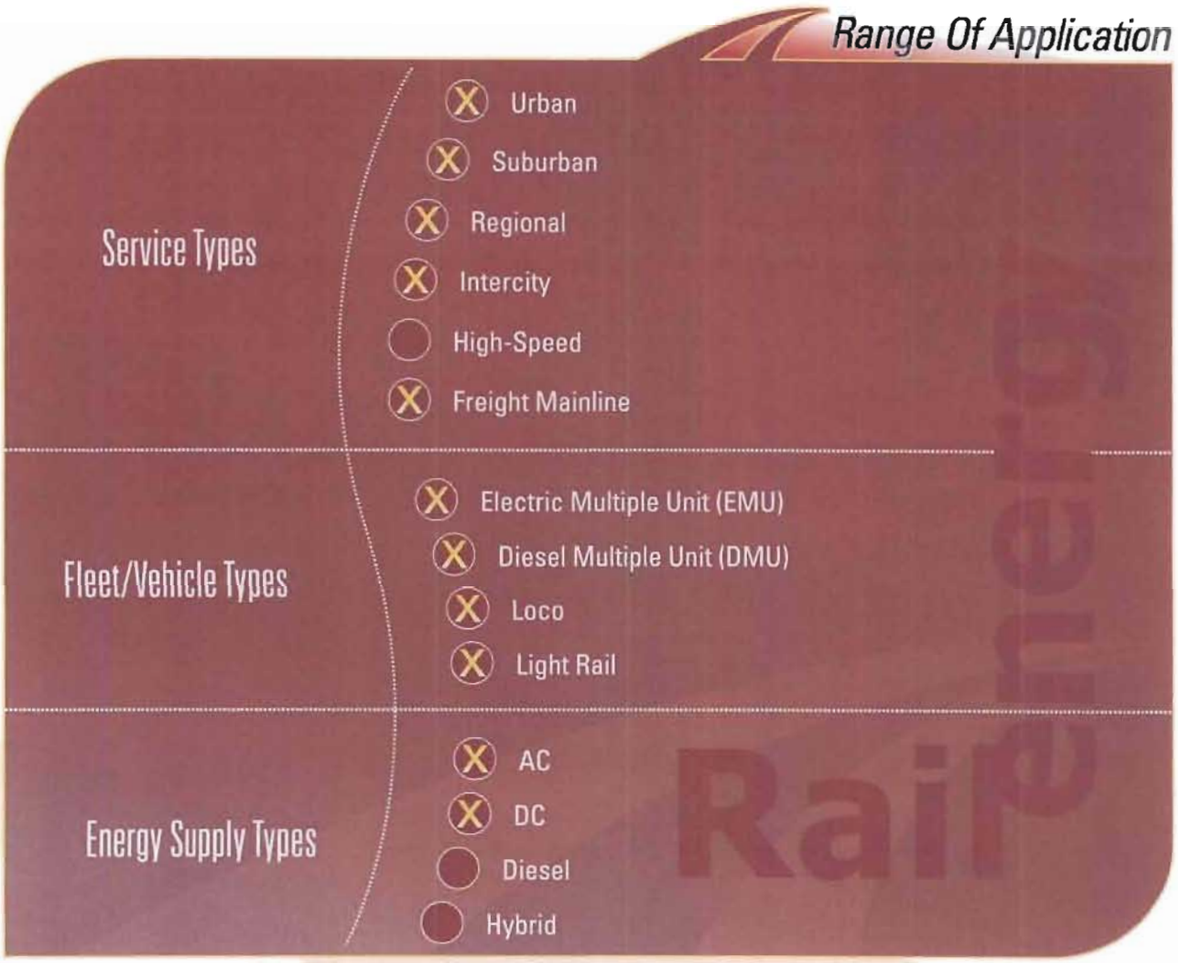
Energy saving potential

Real time management					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	4-6%	1-2%	0-2%	Not applicable	Not applicable
DC 3 kV	4-6%	1-2%	0-2%	Not applicable	Not applicable
AC 15 kV 16,7 Hz	4-6%	1-2%	0-2%	Not applicable	Not applicable
AC 25 kV 50 Hz	4-6%	1-2%	0-2%	Not applicable	Not applicable
Technology notes	The EE potential of this technology is very depending on the service type (better results when applied on commuter trains)				
Baseline technology	Base line technology could be ATS (Automatic Train Supervision) with energy management or regular line with no technologies for energy management				

Advantages of the new technology

As Real-time management is an entirely new concept, it is difficult to compare with existing technologies. Currently, rail traffic is monitored on a daily basis with the objective of providing on-time freight and passenger services. Economic driving technologies are available and enable energy efficiency on

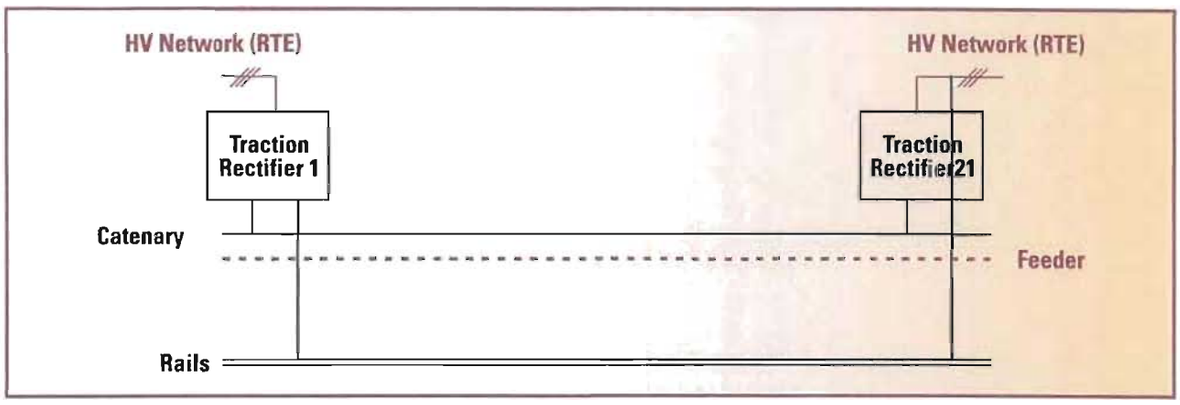
individual trains. Additionally, a rail energy management system optimises a complete train schedule, taking global power constraints into consideration.



IV. 2x 1.5 kV DC traction system

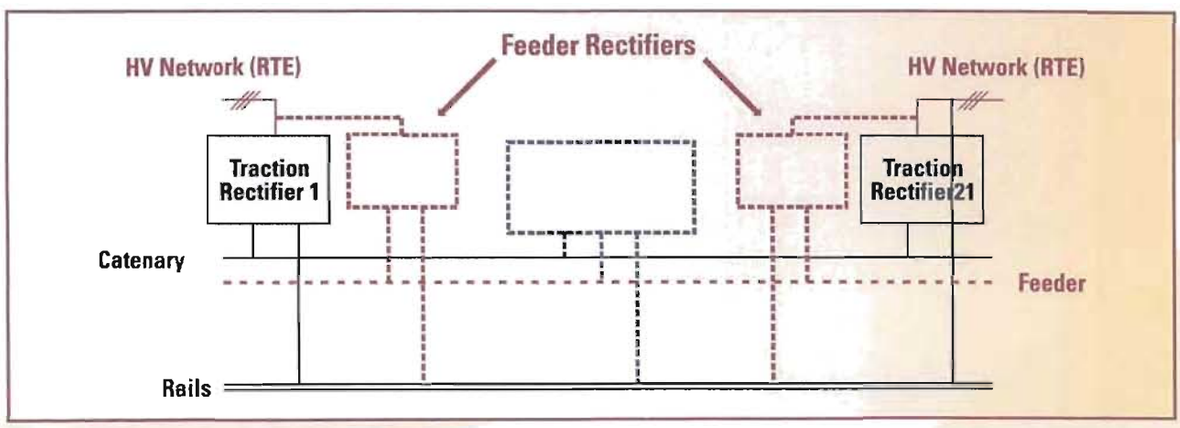
Technology description

The following 1.5 kV DC circuit for a double track is state-of-the-art:



The idea of the 2x1500V is to use existing or new feeders and to set their capacity at a different level to that of the catenary. These feeders are supplied with power by new converters installed in existing substations.

The 2x1.5 kV DC circuit for a double track is to be set up as follows:



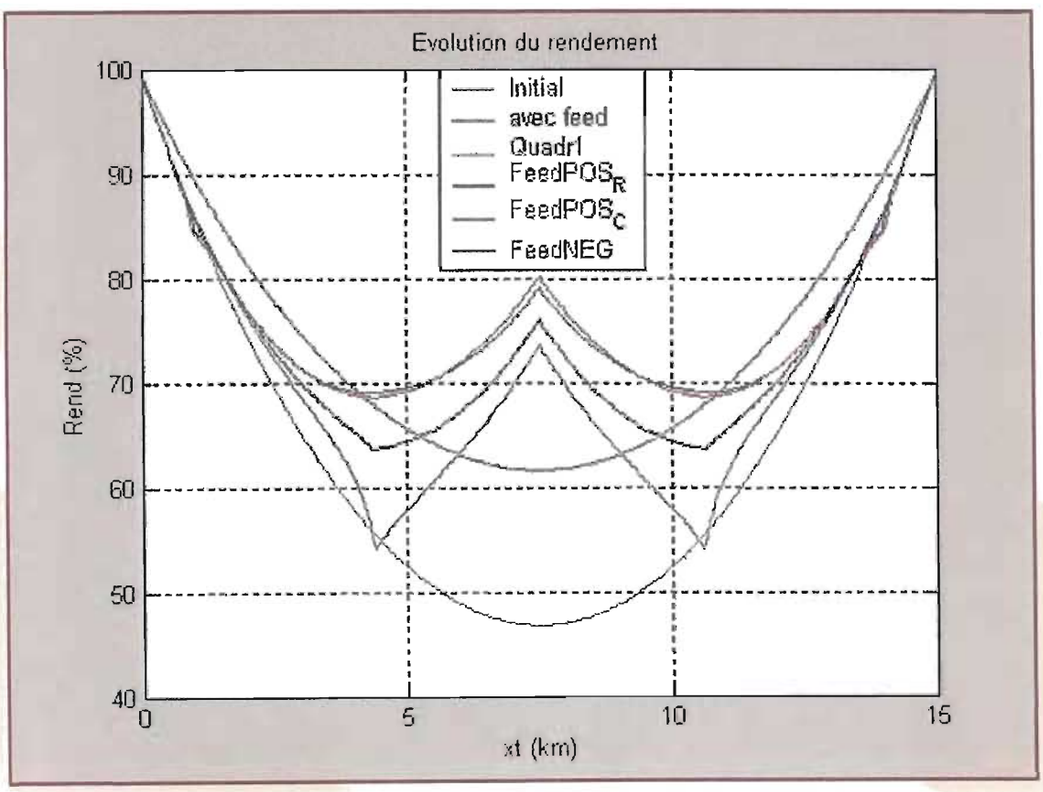
Advantages when compared to existing technologies:

- saves the installation of a new substation
- increases the distance between consecutive substations
- reduces energy required from the grid
- reduces DC losses
- reduces stray DC current

Energy saving potential

2 x 1.5 kV DC traction system					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	2-4%	2-4%	2-4%	Not applicable	2-4%
DC 3 kV	2-5%	2-5%	2-5%	Not applicable	2-5%
Technology notes	This technology applies wherever:-The energy issued from dynamic braking is important, itself influenced by the frequency of stops, motor rate of trains, line gradients,-The natural receptivity of the line can be improved to near 100%, itself influenced by off-peak operational headways, small train auxiliaries power consumptions, reduced value of system line voltage or significant line losses				
Baseline technology	"Normal" DC sub-station with unidirectional DC substation with natural exchange of braking energy between regenerative trains (natural line receptivity) =Actual State of the art				

The following graphs show how the efficiency of the scheme changes depending on where trains pass each other. This efficiency is calculated using the formula $\frac{P_{LOC}}{P_{ss}}$ where P_{LOC} is the power required by the train (the equivalent of two trains passing each other) and P_{ss} is the total power supplied by the converters.



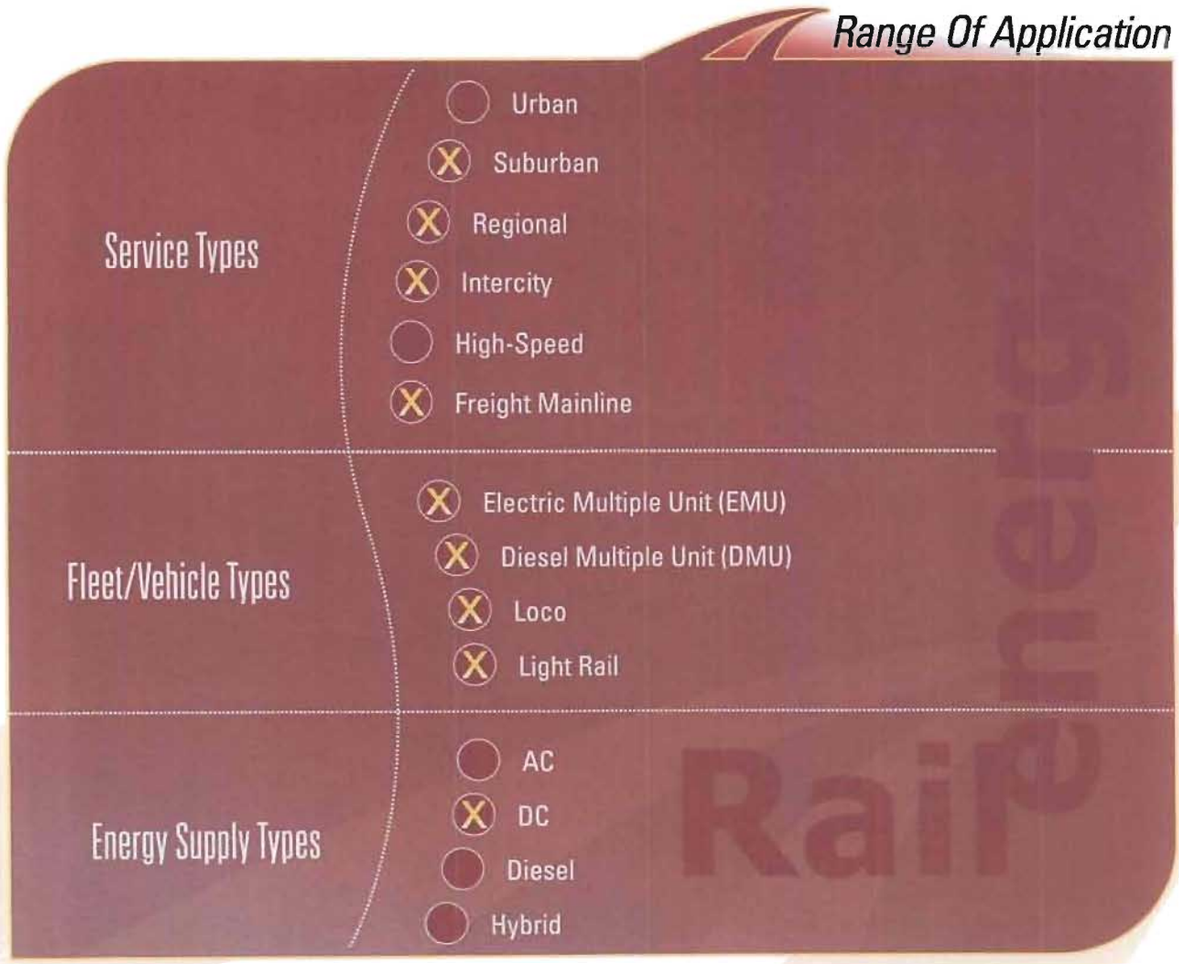
Evolution du rendement = change in efficiency Rend (%) = efficiency (%)Avec feed = with feed

Levels of efficiency displayed here present a clear picture of losses in rails, the catenary and feeder(s).

Advantages of the new technology

Owing to the 2x1.5 kV DC system, the main expected results can be seen below:

- reduction in the number of new substations required
- increase the distance between consecutive substations
- reduction in the energy required from the grid
- reduction in DC losses
- saving catenary reinforcements
- making the most of existing feeders
- improving 1.5 kV DC rolling-stock feeding system performance
- reduction in DC stray currents



V. Asymmetrical AT system

Technology description

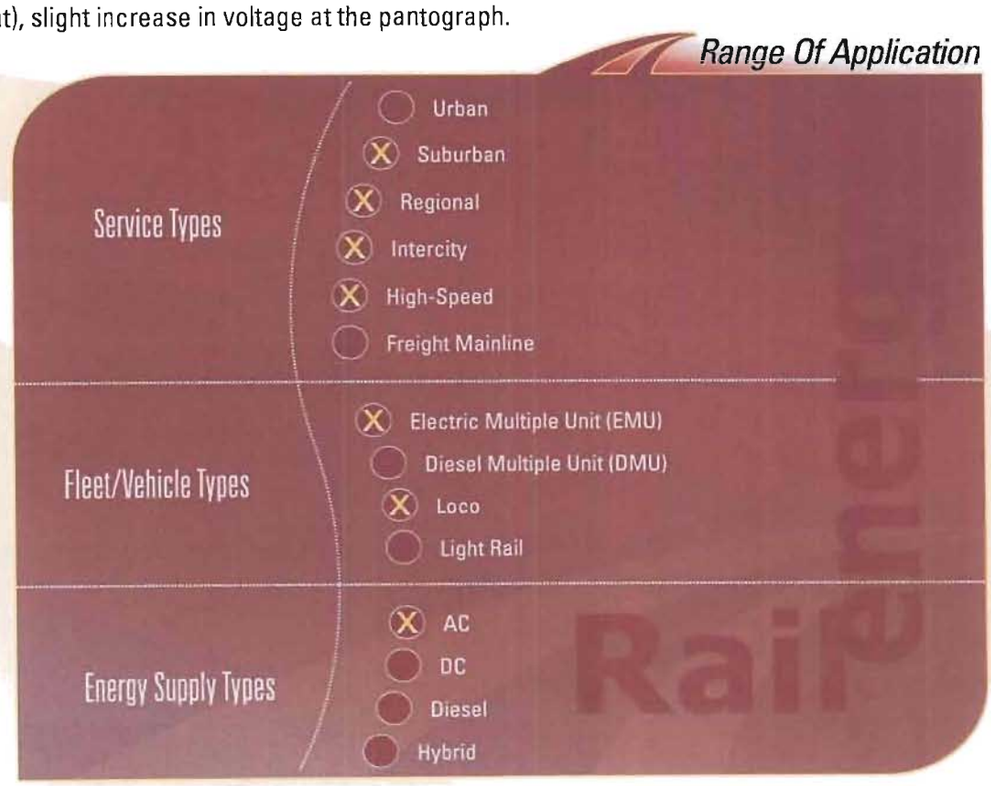
This new technology includes an increase in the rated voltage of the negative feeder in 25kV 50Hz AT systems. Initially the overhead line and track are not changed except for the negative feeder which is moved laterally in order to meet insulation requirements. The effect of the voltage increase is to reduce loop impedance, reduce line currents, increase pantograph voltage for a given train performance, and consequently reduce transmission losses. No attention is paid to distribution of currents with respect to low frequency magnetic fields. The same concepts can also be employed in 15 kV systems.

Energy saving potential

Asymmetrical AT system					
	Service type				
Energy supply type	suburban	regional	intercity	high-speed	freight mainline
AC 15 kV 16,7 Hz	0,5-3,0%	0,5-3,0%	0,5-3,0%	0,5-3,0%	0,5-3,0%
AC 25 kV 50 Hz	0,3-1,0%	0,3-1,0%	0,3-1,0%	0,3-1,0%	0,3-1,0%
Technology notes	Technology not dependent of service type; slightly higher savings expected for lines with higher train frequency due to higher ratio of load and capacity .				
Baseline technology	Information missing				

Advantages of the new technology

Very low to low reduction in energy losses (baseline technology may already have very high efficiency if it is recent), slight increase in voltage at the pantograph.



VI. Parallel substation

Technology description

The approach of the new technology parallel substation for AC 25 kV railway power supply systems balances load flow control in three-phase distribution, which may be able to deal with the challenges arising from connecting substations in parallel to a three-phase high-voltage transmission grid.

Usually, AC 15 kV 16.7 Hz railways systems have a double-sided power feed, thus permitting larger feeding distances and fewer substations. This option has been discussed for many years, also for 50 Hz power supplies, where until now single-sided feeding prevails. However, in recent years various technologies for balancing load flow control in three-phase distribution systems have been developed, which may be able to deal with the challenges arising from connecting substations in parallel to a three-phase high-voltage transmission grid. The parallel substation technology for 25 kV 50 Hz systems can be used for two different purposes:

1. Energy saving application: by using conventional distances between substations of AC 25 kV and 2AC 25 kV 50 Hz systems.

2. Reduction of investment costs: by lengthening distances between substations (for new tracks).

Energy saving potential

Parallel sub-station					
	Service type				
Energy supply type	Suburban	regional	Intercity	high-speed	freight mainline
AC 15 kV 16,7 Hz	Already baseline	Already baseline	Already baseline	Already baseline	Already baseline
AC 25 kV 50 Hz	0,5-2,0%	0,5-1,5%	0,5-1,0%	0,4-1,0%	0,5-1,0%
Technology notes	Main improvement is not on energy, but the possibility to drastically reduce the investment for traction power. Parallel feeding allows to enlarge the sub-station spacing!! Energy saving limited to reduction of losses and marginally improved regeneration.				
Baseline technology	Single side fed system 2AC 50/25kV (autotransformer system) or 1 AC 25kV. Each sub-station fed by 3AC HV grid individually. For 1AC 25 kV 16.7Hz systems this parallel feeding is already the baseline!				

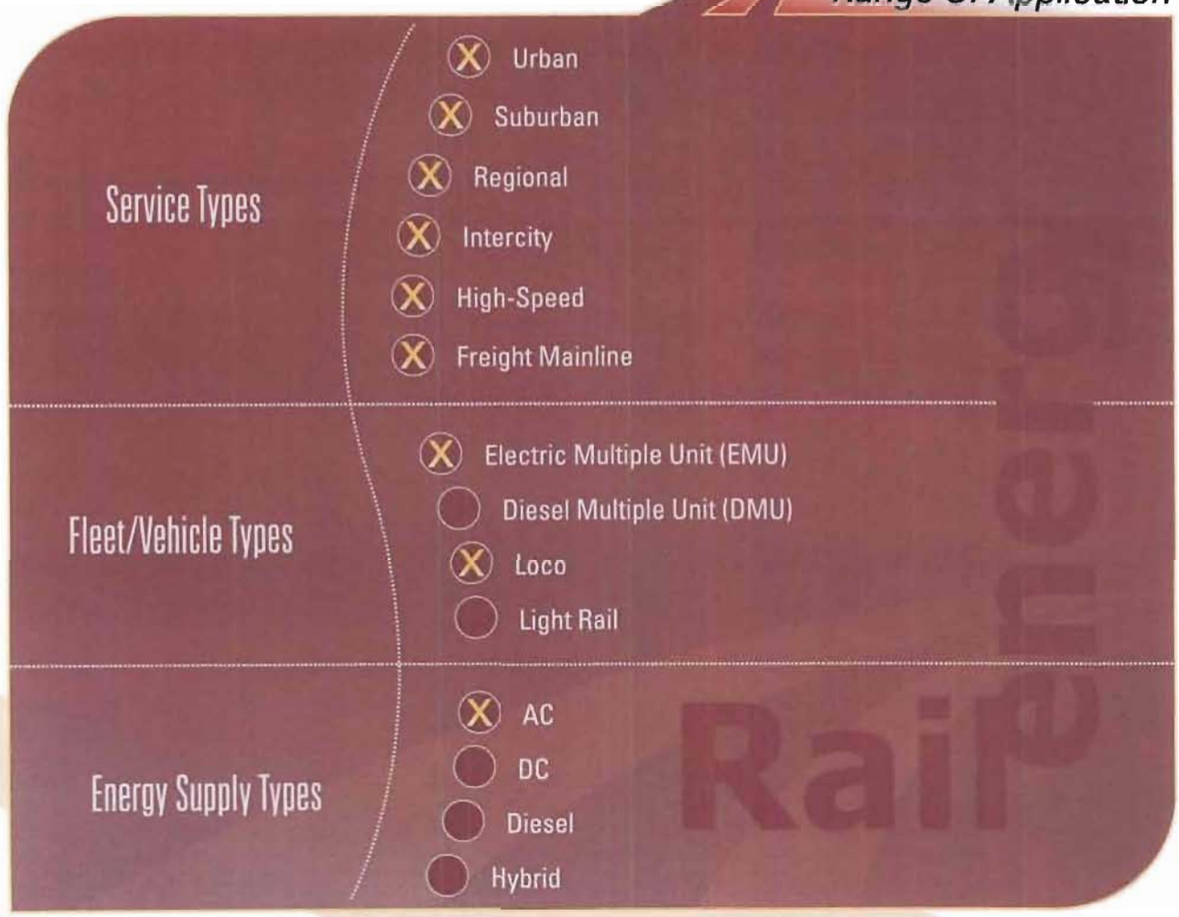
Advantages of the new technology

1. Energy saving application:
   for AC 25 kV 50 Hz and 2AC 50/25 KV 50 Hz, the transmission losses along the line can be reduced and slightly increased regeneration is expected.

2. Reduction of investment costs:

- AC 25kV 50 Hz and 2AC 50/25 KV 50 Hz can be configured with considerably enlarged feeding sections, hence requiring less investment in substations and connections to the three-phase high-voltage grid.

Range Of Application



VII. Increased line voltage

Technology description

The DC 4 kV system can be regarded as an upgraded DC 3 kV system.

By using higher nominal voltages both transmission efficiency and regeneration can be improved considerably. The DC 4 kV system demonstrates considerably improved energy efficiency and permits increased substation spacing.

For higher supply voltages (e.g. 4 kV) the substation equipment and the electronic devices of the trains have to be adapted to this voltage level. Whether changes would be necessary in current 3 kV systems is dependant on the level of insulation on the existing overhead line equipment.

Considerable investment in research and modifying existing installations could therefore be necessary. On the other hand, taking into account ongoing developments in semiconductor technology, this might become an attractive option for high-power systems, though not in the immediate future.

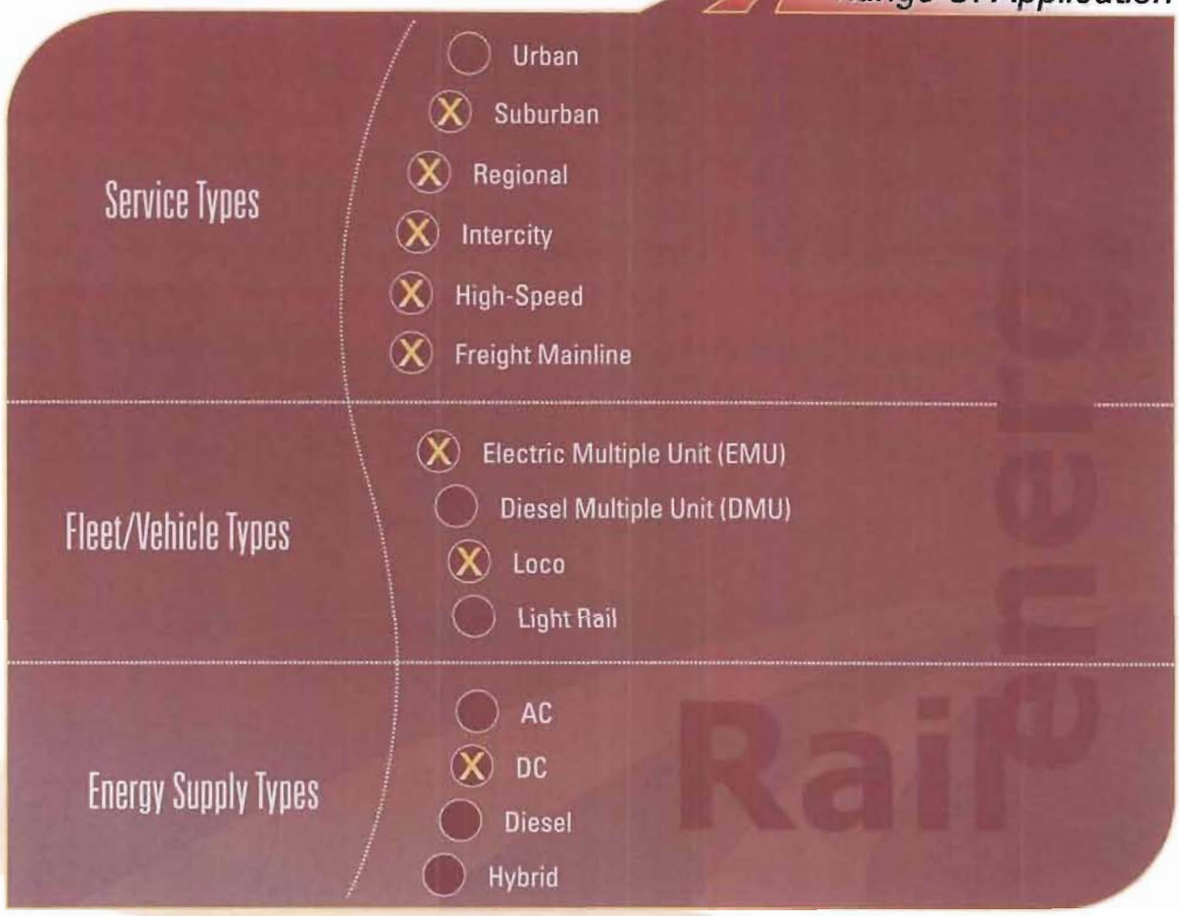
Energy saving potential

Increased line voltage (4kV)					
	Energy saving potentials				
Service type	suburban	regional	intercity	high-speed	freight mainline
Energy supply type					
DC 3 kV	5-15%	5-12%	4-10%	2-7%	2-3%
Technology notes	Higher system nominal voltage of 4kV - not to be compared with today's situation where 3kV is already upgraded to 3,3-3,9 kV. This is meant as a proposal for new architecture requiring new standards even for the vehicle equipment. Main saving is on improving recuperation conditions and reducing line losses. New development necessary for power electronics and circuit breaker technology both for rolling stock and sub-stations.				
Baseline technology	Standard 3 kV DC-system (e.g. 20km sub-station spacing, OHL parallel feed; no load voltage approx. 1,1*Un)				

Advantages of the new technology

- Increased system performance due to higher train voltage
- Possible increase in substation spacing
- Reduction in line losses
- Higher regeneration rates

Range Of Application



VIII. Reduced line impedance

Technology description

The approach of the new technology reduced line impedance consists of the reduction of losses along the line of electrified railway systems. The losses are caused by the impedance/resistance of the contact line system and the current which is supplied to the locomotive vehicles.

The reduction in impedance/resistance is achieved through higher conductivity of the materials of the contact line systems and/or by enlarged cross sections of contact line systems.

1. AC-systems:
   reduced line impedance is achieved using better quality magnesium alloyed copper conductors (CuMg) or other advanced copper alloys for high-use systems. The manufactures of contact wire produce CuMg conductors with improved electric conductivity and less manufacturing tolerances, these features are guaranteed for the material. Hence the effective contact line resistance, causing the thermal losses of the catenary, is reduced. Where reinforcing feeders are used, the appropriate cross sections and conductivity should be optimised, especially with regard to losses.

2. DC-systems:
   increasing effective copper cross section of DC-lines in order to reduce line losses by means of lower resistance and reduced voltage drop.

Energy saving potential

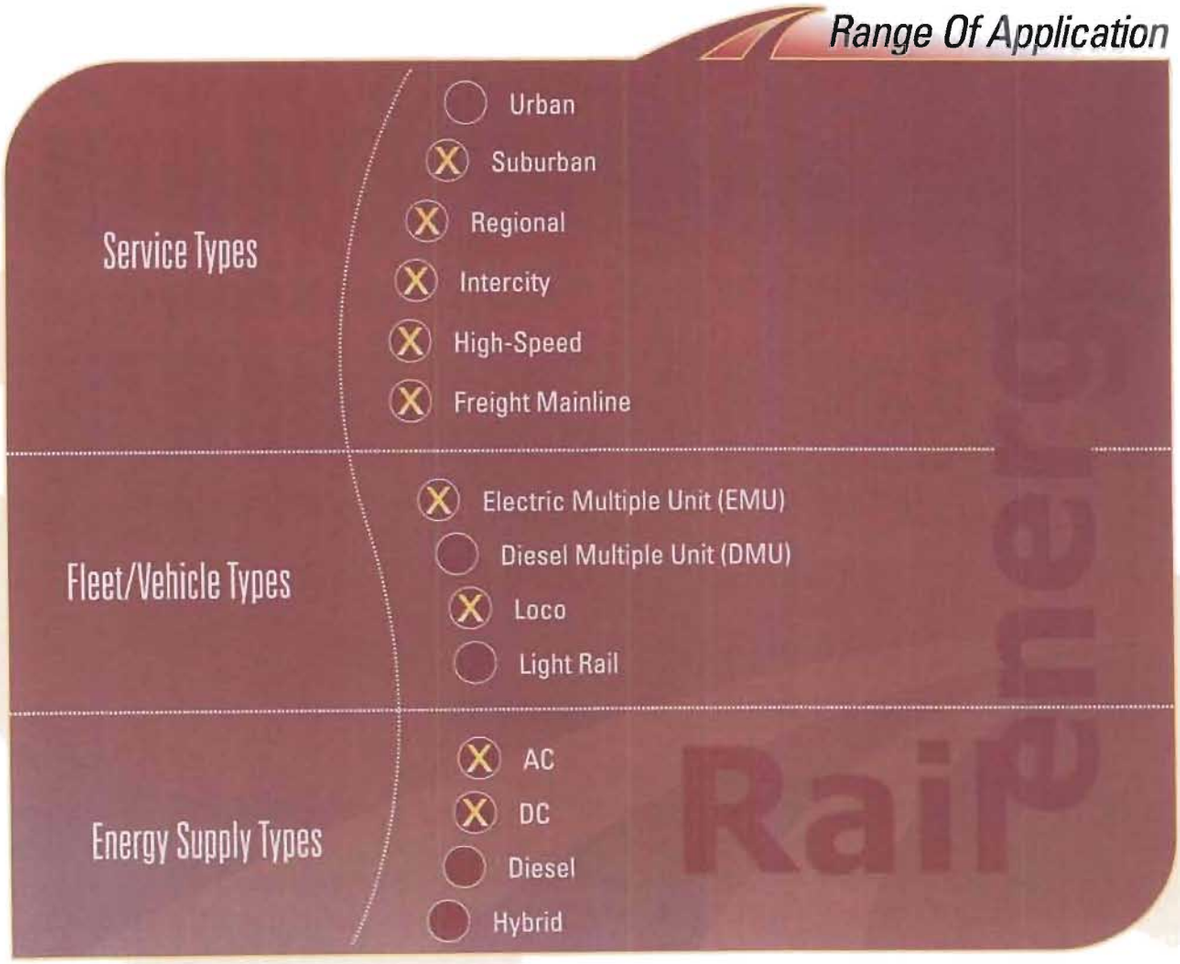
Reduced line impedance					
	Energy saving potentials				
Service type / Energy supply type	suburban	Regional	intercity	high-speed	freight mainline
DC 1,5 kV	1-5%	1-4%	0,5-3%	Not applicable	1-4%
DC 3 kV	1-8%	1-5%	1-5%	1-4%	1-4%
AC 15 kV 16,7 Hz	1-2%	1-2%	1-2%	1-2%	1-2%
AC 25 kV 50 Hz	0,5-1,0%	0,5-1,0%	0-0,5%	0-0.3%	0,05-0,5%
Technology notes	For AC High-speed small reduction due new contact wire material. For DC and AC other than High-speed an enlarged (energy efficient) cross section. The decreased impedance (resistive part when only increasing conductivity or also impedance with additional conductor) decreases losses and may also increase recuperation because of less voltage drop				
Baseline technology	High-Speed: OHL with standard Copper Magnesium contact wire Other service type with normal OHL rated according to thermal load and voltage drop				

Advantages of the new technology

Increased electric conductivity of catenary conductors leads to a reduction in transmission losses in the contact line system. This technology is the simple approach.

1. AC-systems:
   losses in the traction power supply for AC systems, when compared to the energy demand of the whole system (point of common coupling), fall in the range of 3-5%. Investment in infrastructure is only partly recommended because of low potential energy savings for AC systems. Application of contact line material with higher conductivity is advised in the course of regular contact line replacement.

2. DC-systems:
   losses in traction power supply for DC systems, when compared to the energy demand of the whole system (point of common coupling), fall in the range of 10-35%. Investment in infrastructure is recommended because of high potential energy savings for DC systems. The application is implemented by increased cross sections of contact wires/messenger wires and/or additional feeder wires.



IX. Trackside energy storage

Technology description

Introduction of trackside energy storage units to absorb energy generated by braking vehicles and store it until it can be fed back into the power supply system by the storage unit when vehicles are accelerating.

The storage system operates in parallel with the existing traction power supply system and is based on double-layer capacitor technology.

Trackside energy storage can be used in two different operation modes:

1. Energy saving application:
   trackside energy storage absorbs energy generated by braking vehicles and stores it until it can be fed back into the power supply system by the storage unit when vehicles are accelerating.

2. Voltage stabilisation:
   trackside energy storage operates as a voltage stabiliser. Energy levels are kept high and energy is released when system voltage falls below a specified limit.

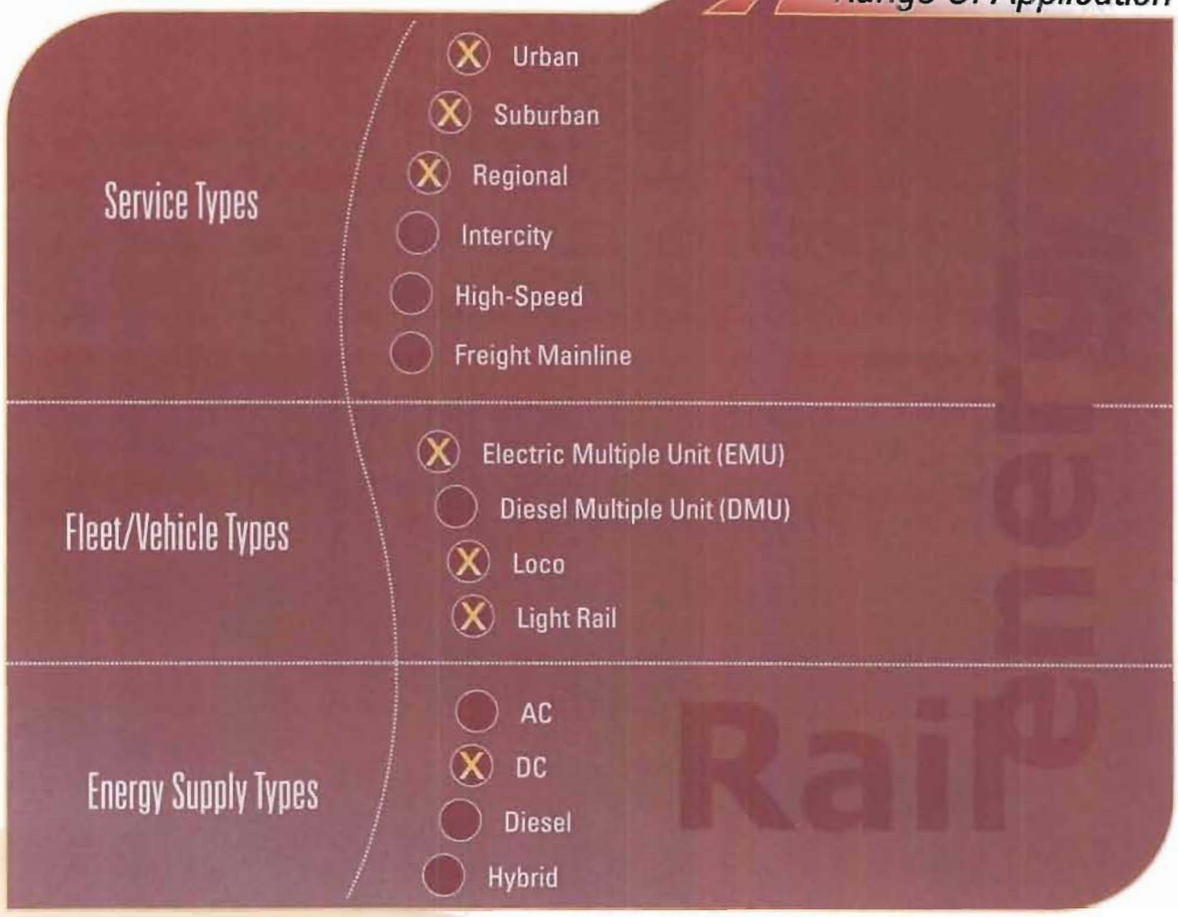
Energy saving potential

Trackside Energy Storage Unit					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	3-10%	3-10%	1-5%	Not applicable	1-5%
DC 3 kV	3-10%	3-10%	1-5%	1-5%	1-5%
Notes	The frequency of the braking is very important for the EE potential of this technology (distance between stops, headway, voltage and sub-station spacing). The saving also depends on the number and location of ES-Units: e.g. only at sub-stations or also at stations stops.				
Baseline technology	"Normal" DC sub-station (uncontrolled rectifier)				

Advantages of the new technology

- Improved utilisation of regeneration.
- Peak power limitation
- Increased system performance in terms of train supply voltage
- Technology can be used without changing the existing system, just by adding new components at certain locations, in contrast to the competing inverter technology which requires permission for connection to the power supply and most likely modifications in the connection.

Range Of Application



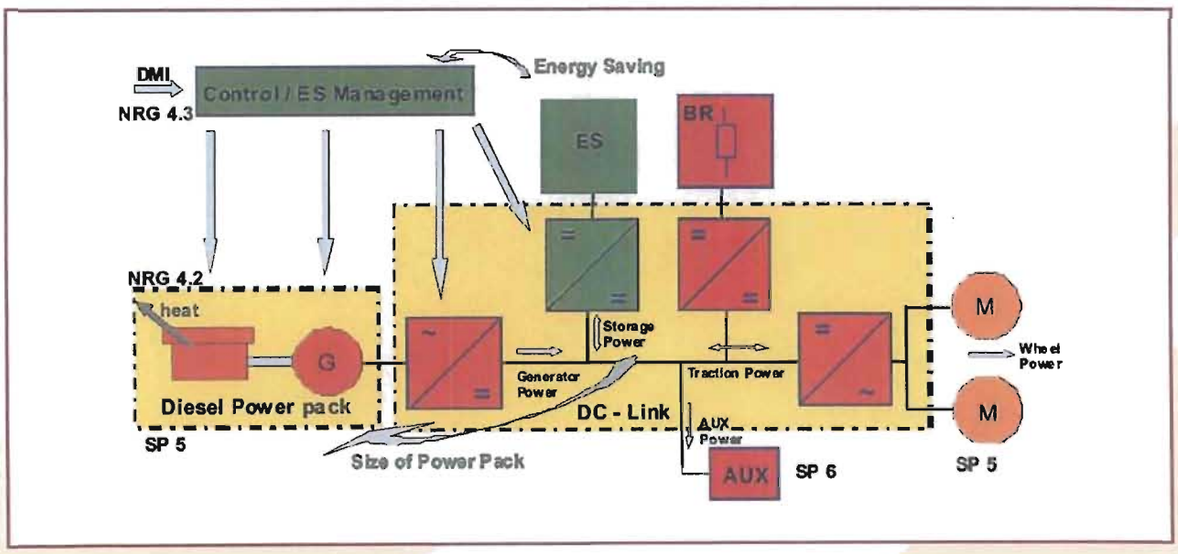
X. Onboard energy storage

Technology description

Onboard energy storage systems represent enormous potential for energy saving in traction applications. Diesel Multiple Units are probably the most suited vehicle type where energy storage and reuse of recovered brake energy can lead to energy savings of up to 30 or 40%. These savings can be measured directly in terms of reduced fossil fuel consumption per 100km. In addition, there will be emission savings of the same order or even higher since the small diesel engine can be operated in an optimal fashion. The optimal size and operation mode of such a storage system depends on the application under consideration and operational conditions.

The system layout which is considered for the selection of the technology is shown in the figure below. It consists of a diesel power pack comprising a diesel engine and a generator based on the asynchronous or synchronous principle, with an active or passive rectifier delivering the DC-Link power which is fed through the inverter to the traction motors supplying wheel power.

During braking the wheel power is transferred to the DC-Link through the inverter and either stored or dissipated via heat in the brake resistor. Both components are connected to the DC-Link via a controlled chopper allowing the power distribution between both components to be changed.



Energy saving potential

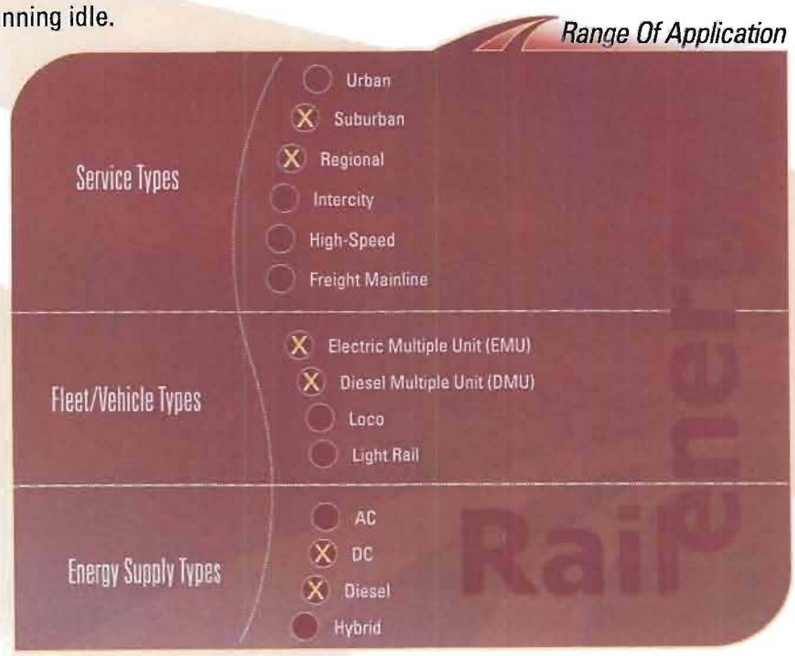
On-board energy storage - supercaps					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	5-15%	5-15%	Not applicable	Not applicable	Not applicable
DC 3 kV	4-12%	4-12%	Not applicable	Not applicable	Not applicable
Diesel	Not Applicable	5-20%	2-8%	Not applicable	Not applicable
Technology notes	Onboard energy storage enables the traction equipment to store braking energy which could be reused during acceleration. There are mainly two main saving aspects when taking into account onboard energy storage: Time sav ings, which correspond to the capability of supplying additional power to the DC link in Booster operation. Energy saving, which corresponds to the capability of operating the diesel in an energy optimized range or shorter operatio n when using the booster operation and applying coasting with diesel in idle mode.				
Baseline technology	Present vehicles with electric equipment only comprise a brake resistor, who is burning the brake energy in case no recuperation is possible. For the considered Diesel Multiple units no recuperation is possible, so during braking, the brake energy is wasted. During acceleration all energy and power needed for this process has to be delivered by the diesel engine.				

Advantages of the new technology

Onboard energy storage enables the traction equipment to store braking energy which can be reused during acceleration.

There are two main saving aspects when considering onboard energy storage:

- time saving, which corresponds to the capability of supplying additional power to the DC-Link in
- booster operation.
- energy saving, which corresponds to the capability to operate the diesel engine in an energy
- optimised range or shorter operations when using the booster operation and coasting with the
- engine running idle.



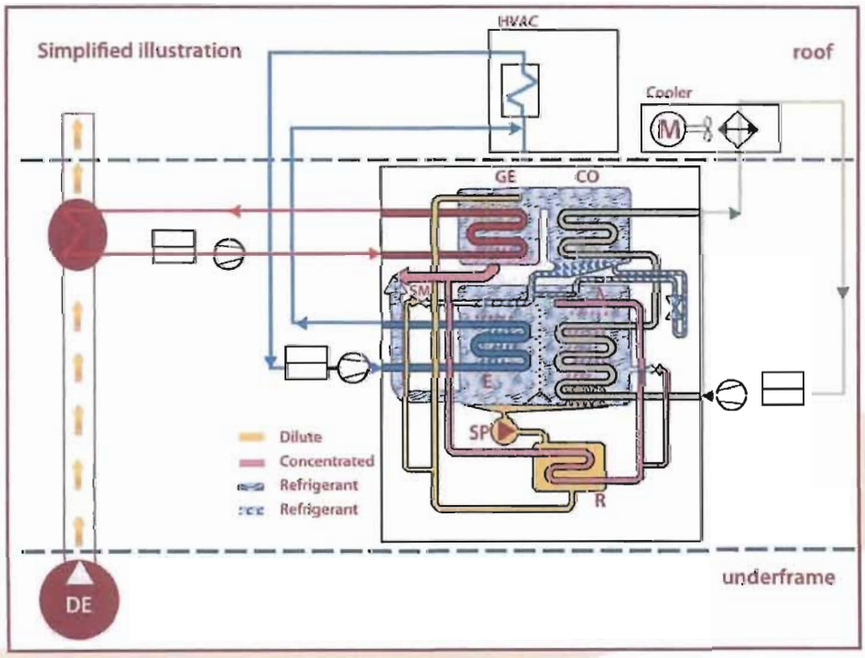
XI. Waste heat usage by using absorption refrigeration

Technology description

This technology enables the re-use of waste heat from a Diesel Multiple Unit (DMU) for heating and cooling. The use of the waste heat from the diesel engine cooling circuit is state-of-the-art. The re-use of the waste heat leads to a reduction in demand for auxiliary power and, furthermore, cuts fuel consumption.

In the foreseeable future, new solutions will be available to implement absorption refrigeration machines in mobile applications.

The following figure shows a simplified schematic overview of an absorption refrigeration chiller. The waste heat is provided by the exhaust air from the diesel engine.

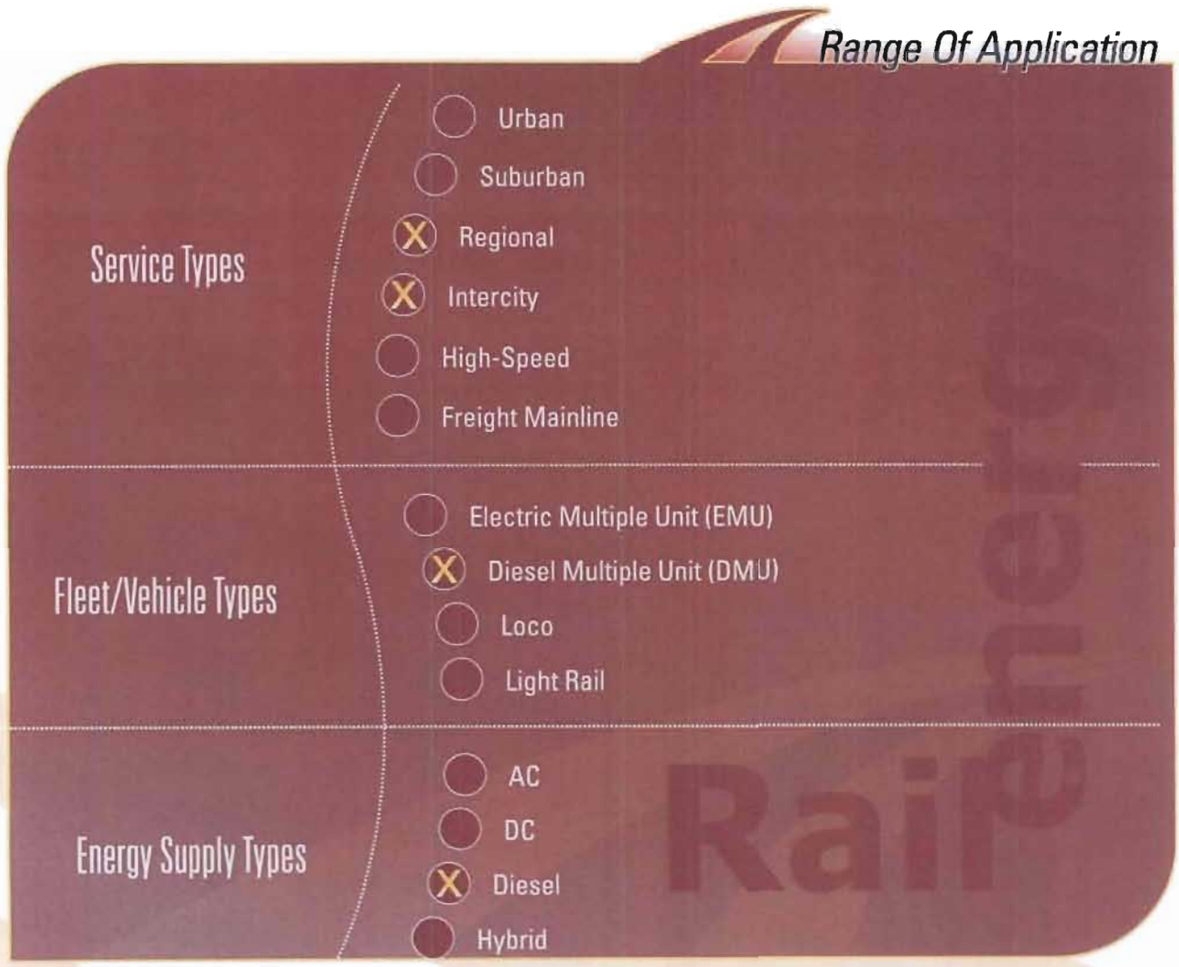


Energy saving potential

Use of waste heat					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
Diesel	Not applicable	1,5-3,5%	1,5-3,0%	Not applicable	Not applicable
Technology notes	Waste heat of the exhaust air of the diesel engine is used to provide an absorption refrigeration chiller for heating and cooling of the passenger compartment and the drivers cabin.				
Baseline technology	Conventional Air Conditioning (HVAC) with waste heat usage for heating provided by the waste heat of the diesel engine cooling circuit.				

Advantages of the new technology

A significant reduction in fuel consumption can be achieved using exhaust air from the diesel engine, the energy from which would normally be lost, for heating and for cooling.



XII. Superconducting Traction Transformer System

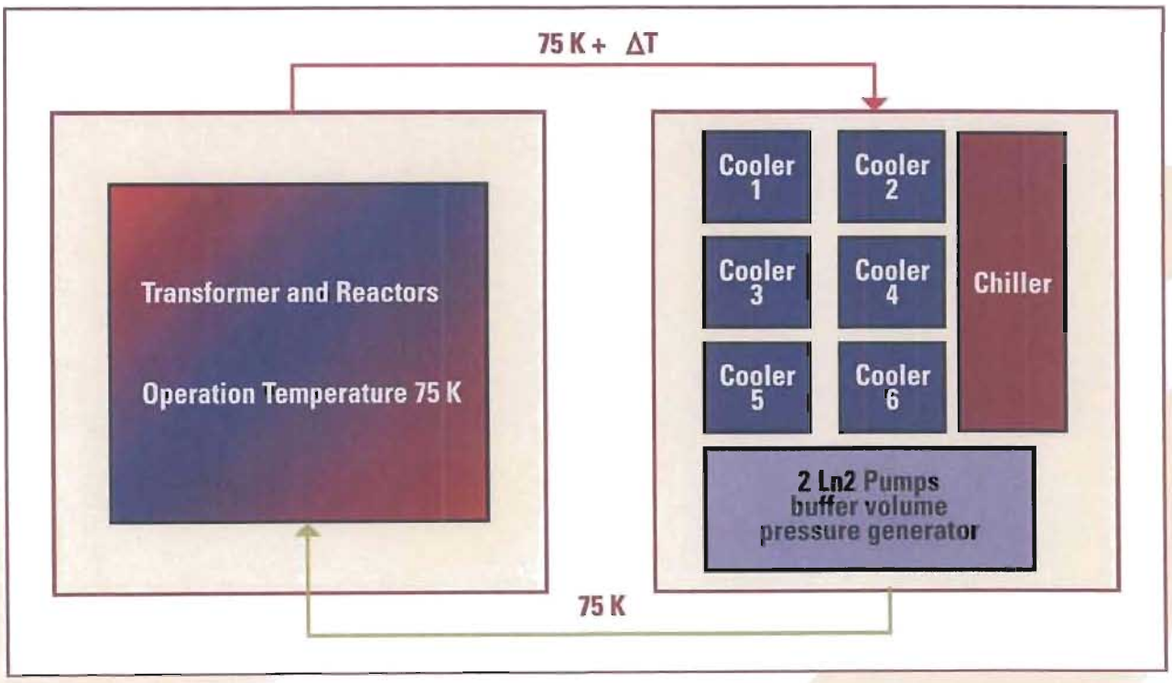
Technology description

A 4.6 MVA Superconducting Traction Transformer System (STTS) including Transformers, Reactors and Closed-Cycle Cryogenic Cooling System can be used in energy efficient traction systems for high-speed passenger trains. The transformer can be applied in multi-system trains for international operations in countries using AC 16.7 Hz/15 kV and AC 50 Hz / 25 kV.

Schematic lay-out of a Superconducting Traction Transformer System

The STTS consists of an active part (left side) including the transformer itself and the traction reactors with iron core and high-temperature superconducting (HTS) windings and the vacuum isolated cryogenic vessel with liquid nitrogen enclosing the HTS-windings.

The cooling system (right side) regulates the system operation temperature of 75K (=minus 198 °C). It consists of several coolers (e.g. 6) to control refrigeration capacity by on/off switching of coolers and to ensure redundancy. For the operation with pressurized nitrogen LN2 pumps, a coolant buffer volume and a pressure generator is required. A chiller pre-cools the cooling air for the cryo-generator.



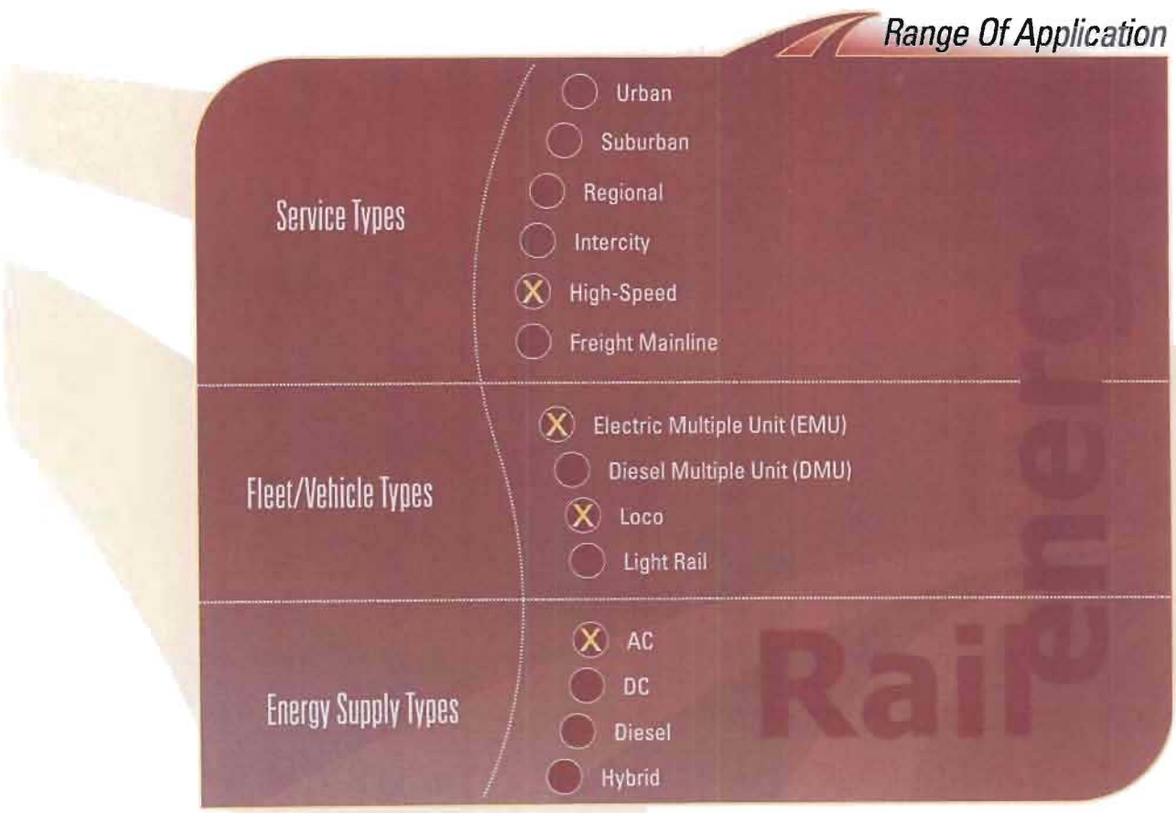
Energy saving potential

Superconducting transformers and inductances					
	Energy saving potentials				
Service type / Energy supply type	Suburban	regional	intercity	high-speed	freight mainline
AC 15 kV 16,7 Hz	Not relevant	0-6%	2-6%	5-7%	Not relevant
AC 25 kV 50 Hz	Not relevant	0-4%	1-4%	3-5%	Not relevant
Technology notes	High-Temperature Superconductor (HTS) traction transformers provide a high energy saving potential due to their high efficiency of over 99% compared to about 92% for conventional copper-oil transformers. The saving potentials on system level in this figure include the onboard cooling system.				
Baseline technology	Cu-oil transformer				

Advantages of the new technology

In comparison to conventional traction transformers (operating at line frequency with copper conductors), a STTS promises the following benefits:

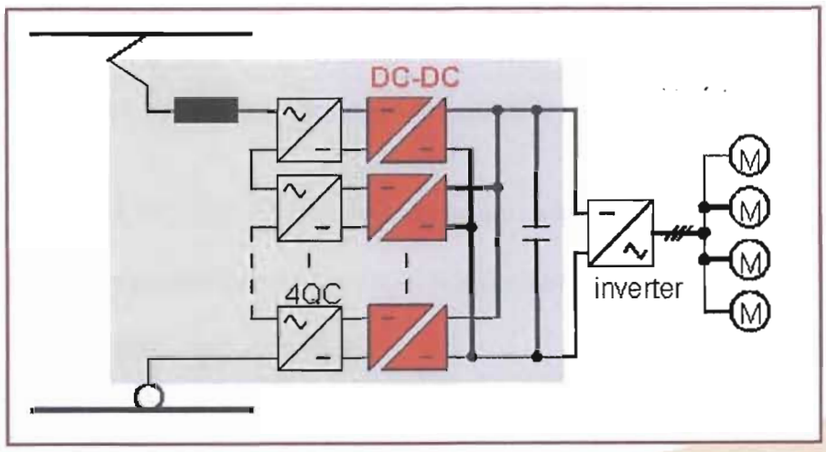
- lower energy consumption, even when the necessary cooling supply is included
- reduced volume and weight
- oil-free operation of transformer and cooling system (environmental benefits, reduced fire hazard)



XIII. Medium frequency traction power supply

Technology description

Medium Frequency Traction Power Supply is a converter which is connected via a line choke to the high line voltage. With this solution, implementation of a line frequency transformer at the power supplys front end can be avoided. It consists of a cascade of 4 quadrant converters, each equipped with an individual DC-link. A high DC-link voltage requires only a low number of sub-converters in cascade. To adapt the DC-links electric potential to the common DC -links feeding the motor inverters, medium frequency (MF) DC/DC converters with MF-transformers, which excel at low mass and volume, are used. By utilizing this technology, savings can be made in both overall mass and energy consumption. The innovative component is the medium frequency and high voltage DC/DC converter that links the primary and secondary DC-links.

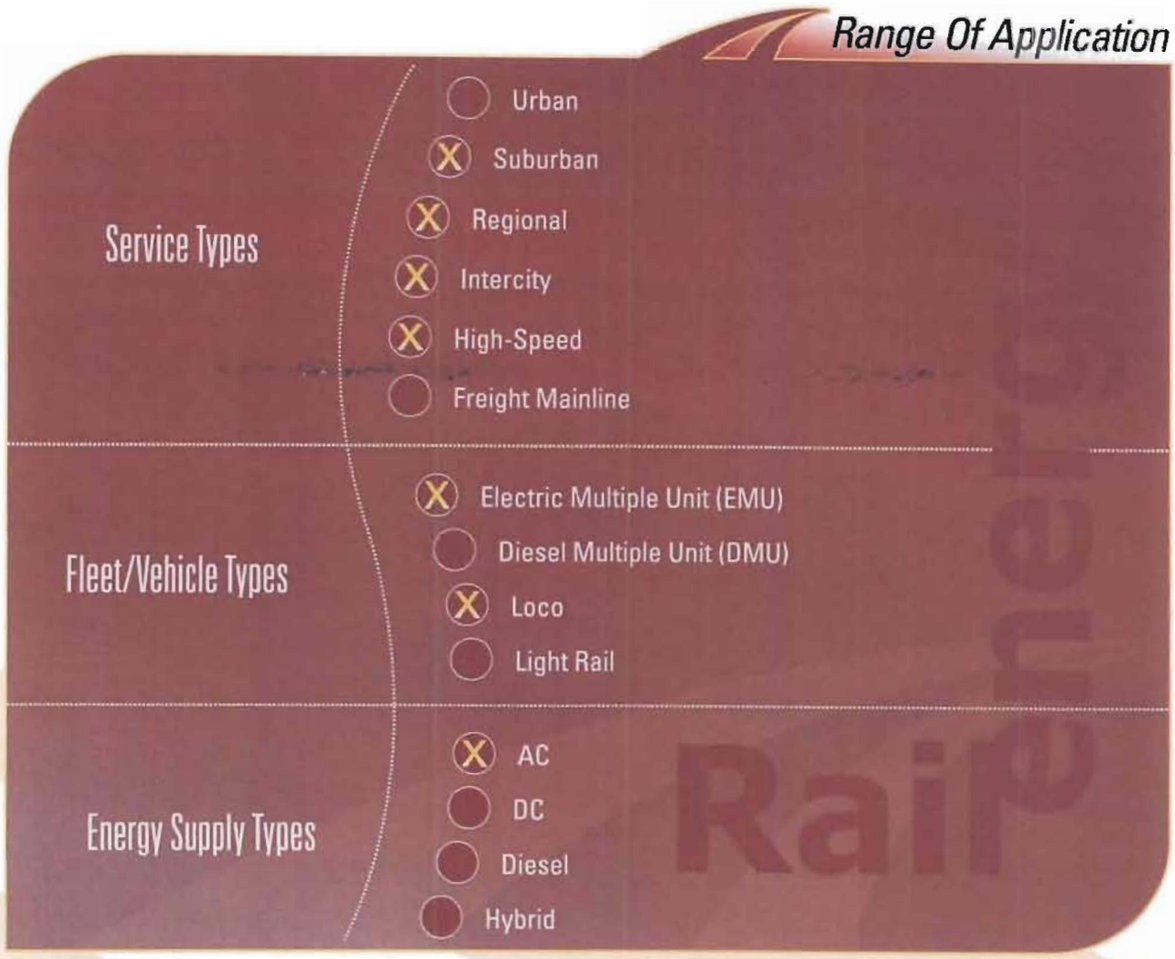


Energy saving potential

Medium frequency energy distribution					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
AC 15 kV 16,7 Hz	3-5%	1-6%	2-5%	3-5%	0-3%
AC 25 kV 50 Hz	0-3%	0-3%	0-3%	1-3%	-2 +2%
Technology notes	This technology replaces a classical transformer with four-quadrant (4Q) converter connected for more complex high voltage power electronics. The key differences to a conventional transformer are: - reliability, availability and redundancy must be considered in a much deeper way - complexity and effort increases with line voltage (25 versus 15 kV) - relatively high low-load losses and low high-load losses - overload capability is limited Saving potentials are highly dependent on drive style (coasting running, all-out-mode), tightness of schedule and chosen line. For comparability same operational cycle must apply.				
Baseline technology	Conventional traction transformer with 4 quadrant converters connected, AC tuned filter in dc-link				

Advantages of the new technology

- Increased efficiency
- Decreased mass savings regarding vehicle construction (axle load limit)
- More flexible installation, e.g. distributed installation



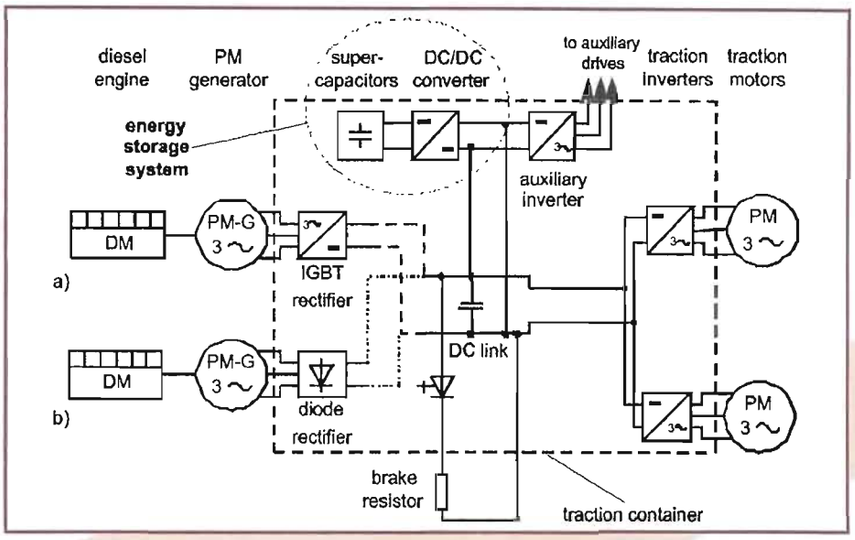
XIV: Hybrid diesel electric propulsion with permanent magnet synchronous machines

Technology description

Permanent magnet synchronous motors (PMSM) can be used as traction motors. PMSMs are lighter and are more compact and efficient than other electric machines.

The energy supply of these traction motors is a diesel engine with a PMSM generator. The generator supplies energy alternatively to a diode and to an insulated gate bipolar transistor rectifier. Both types of rectifier were examined.

From the DC-link of the inverter, auxiliary drives and passenger comfort systems can easily by supplied with power. The integration of an optional DC-link into the energy storage system was also investigated.



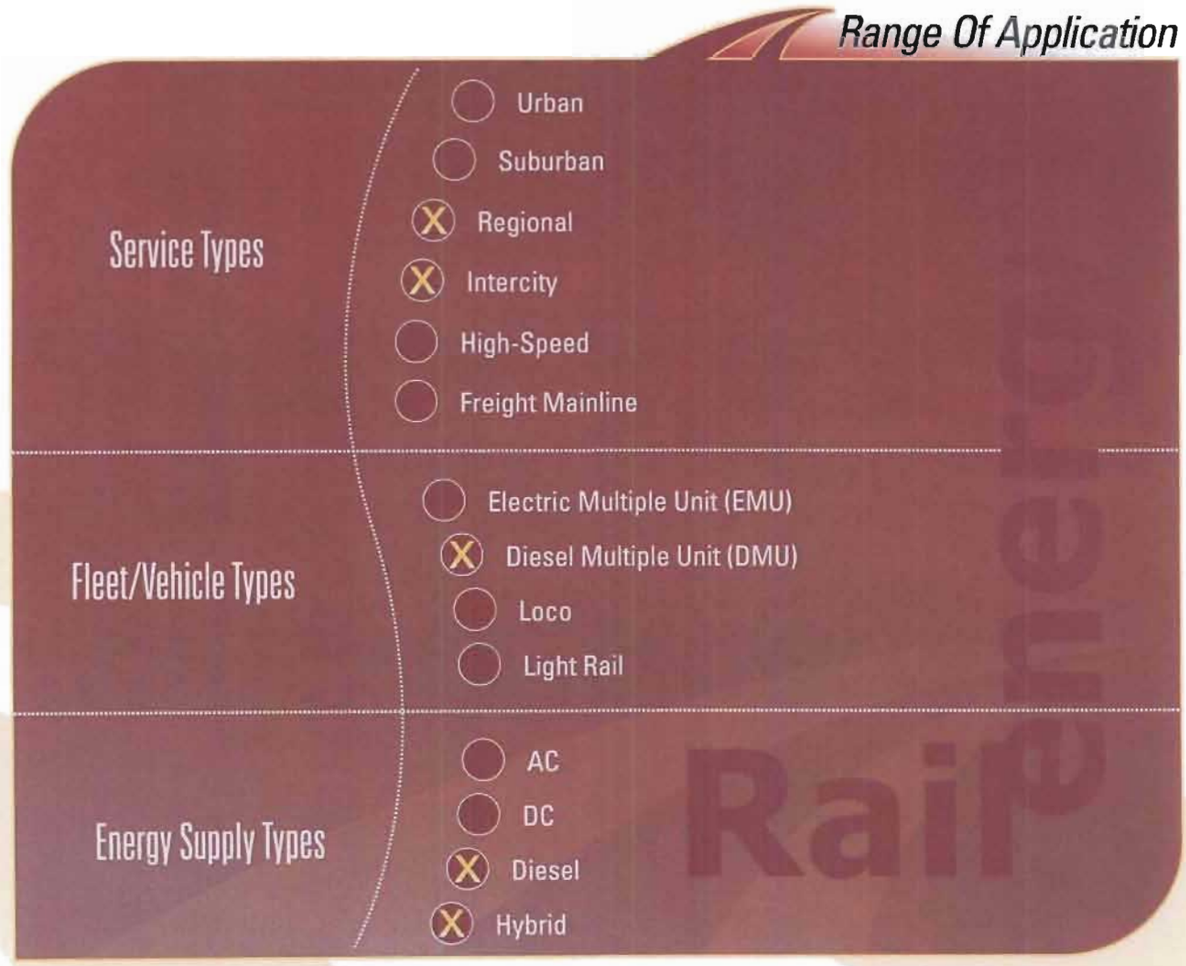
Energy saving potential

Innovative hybrid diesel electric propulsion					
	Energy saving potentials				
Service type / Energy supply type	suburban	Regional	intercity	high-speed	freight mainline
Diesel	Not applicable	4-5% in combination with energy storage: 12-16%*	3-4%	Not applicable	3-5%
Technology notes	Diesel electric propulsion system with permanent magnet synchronous machines for diesel generator and traction motor. Optionally an energy storage is integrated.				
Baseline technology	Diesel electric propulsion system with electric excited synchron generator and induction traction motors				

Advantages of the new technology

The advantages of this technology are:

- efficient operation of the diesel engine
- efficient power supply for passenger comfort systems
- easy integration of an energy storage system, which enables the reuse of braking energy and
- the possibility to downsize the diesel engine at equal traction power.
- more compact and lighter electric motors are used for the generator and the traction motors.



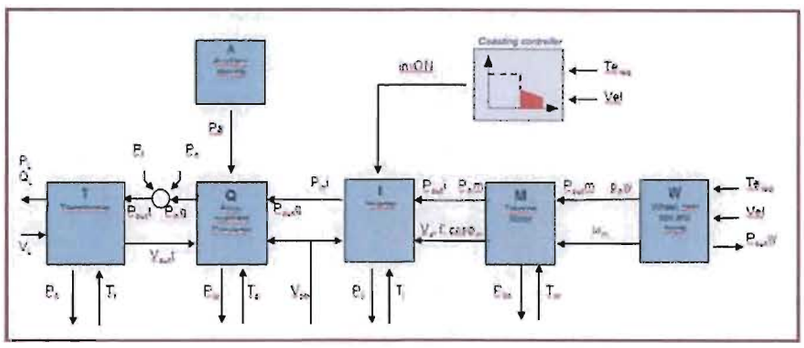
XV. Reduction of vehicle coasting loss

Technology description

Energy consumption of a rail vehicle is closely related to the operating conditions of the main components during normal service.

Inverter and motor losses can represent significant power consumption, as can be seen when the effective power consumed during coasting is examined. Coasting losses increase with speed.

The purpose of this technology is to eliminate traction inverter and induction motor losses due to magnetising current during coasting. To achieve this power saving, new driving styles combined with switching off the power supply to the inverter have been investigated.



Energy saving potential

New converter control technology (applied during vehicle coasting)					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	1-2%	1-3%	1-4%	Not applicable	2-5%
DC 3 kV	1-2%	1-3%	1-4%	1-4%	2-5%
AC 15 kV 16,7 Hz	1-2%	1-3%	1-4%	1-4%	2-5%
AC 25 kV 50 Hz	1-2%	1-3%	1-4%	1-4%	2-5%
Technology notes	The purpose of the technology is to eliminate loss of traction inverter and induction motors due to the magnetizing current during the Coasting, by means of optimisation of traction software. This technology has been integrated in a mixed driving style aimed at maximizing the use of coasting to replace, when possible, of cruising. This driving style is only adaptable to the flat tracks, while it isnt useful i n the uphill climb and in the downhill.				
Baseline technology	For the baseline, traction inverter and motors are kept working during the coasting phase. Coasting driving style between Kufstein and Innsbruck (flat track), all-out driving style from Innsbruck to Brenner (high gradient).				

Advantages of the new technology

During coasting, the inverter could be turned off or the motor flux could be managed to reduce losses. The use of a dedicated algorithm to estimate the motor flux during turn-off will be used in order to achieve a rapid turn-on transient.

Range Of Application

Service Types	○ Urban X Suburban X Regional X Intercity X High-Speed ○ Freight Mainline
Fleet/Vehicle Types	X Electric Multiple Unit (EMU) X Diesel Multiple Unit (DMU) X Loco ○ Light Rail
Energy Supply Types	X AC X DC X Diesel X Hybrid

XVI. Active filtering technology to reduce input passive filter losses

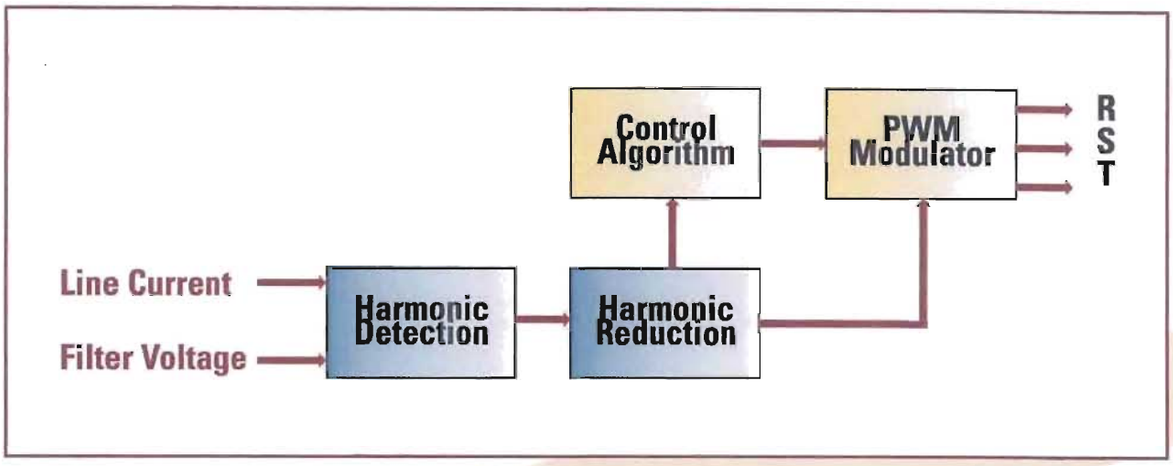
Technology description

The use of active filter algorithms for harmonic reductions was developed specifically for low frequencies, such as 75Hz, in the Netherlands.

The dimensions of the input filter inductor can be reduced and consequently, weight saving can be achieved. The traction inverter is used to compensate for low frequency harmonics.

The fundamental idea is to measure the 75Hz harmonic from the DC-link voltage and to use this signal to perform a proper action:

- on the modulation index of the inverter in PWM (Pulse Width Modulation) mode
- on the fundamental frequency in Full Wave mode

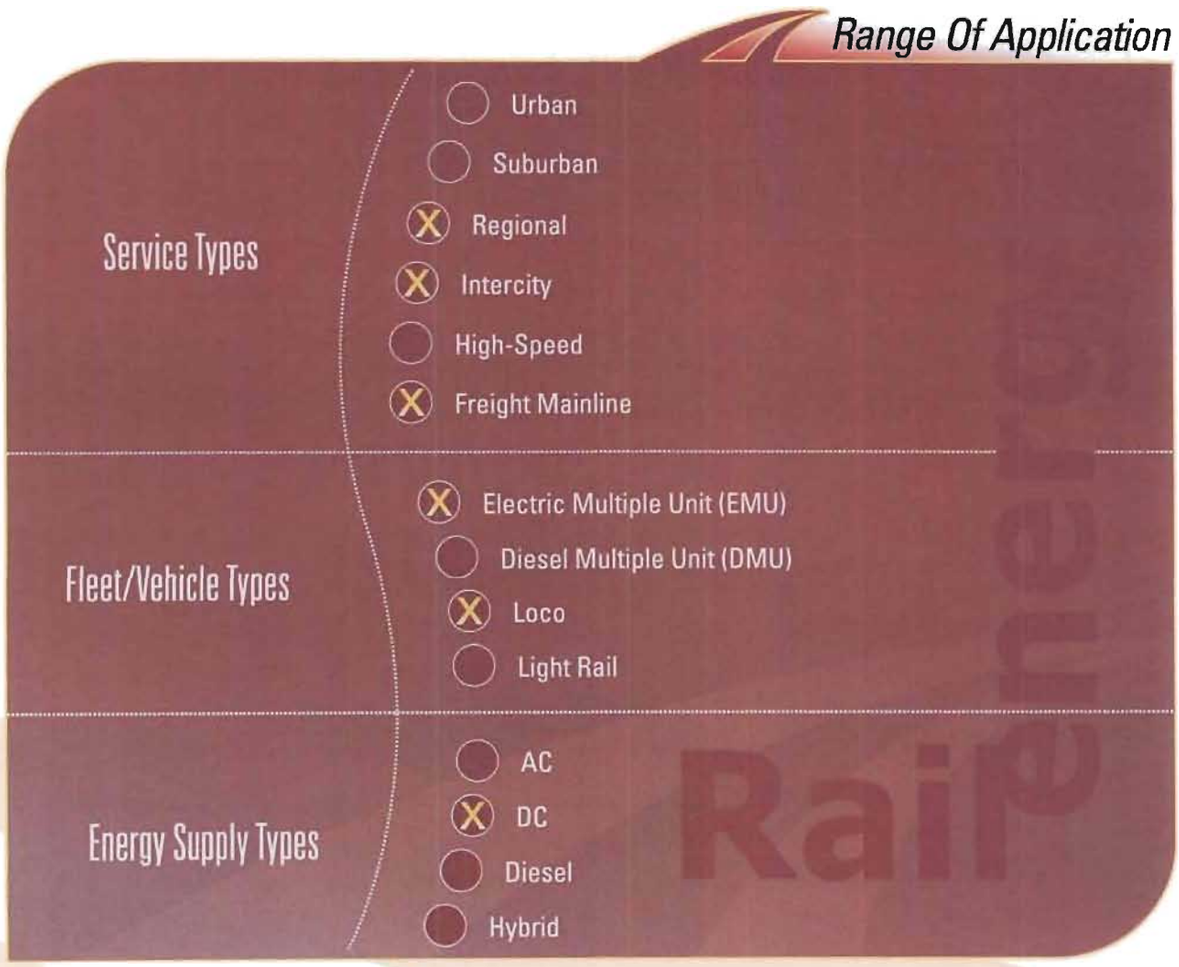


Energy saving potential

Active filtering technology to reduce input passive filter (reactors) losses					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	0,5-1,5%	0,5-1,5%	0,5-1,5%	Not applicable	0,5-1,5%
DC 3 kV	0,5-1,5%	0,5-1,5%	0,5-1,5%	0,5-1,5%	0,5-1,5%
Technology notes	The use of traction converters as an active filter, by means of dedicated algorithms for harmonic reduction, allows weight and dimension reduction of input filter inductors for DC lines.				
Baseline technology	To reduce harmonic components on the line current for DC lines, classical LC filters are used. The inductors are often large and heavy.				

Advantages of the new technology

The active filtering achieves a reduction in size and weight in filter inductance.



XVII. Optimised management of medium voltage loads for energy saving

Optimisation of the auxiliary and cooling systems

Technology description

The proposed technology concerns optimised MV (Medium Voltage) load management for cooling systems.

When maximum cooling performance is not requested, for example at low speed or during the train stops, fans and pumps can operate at reduced speed or be turned off to reduce energy consumption and environmental impact.

Energy saving potential

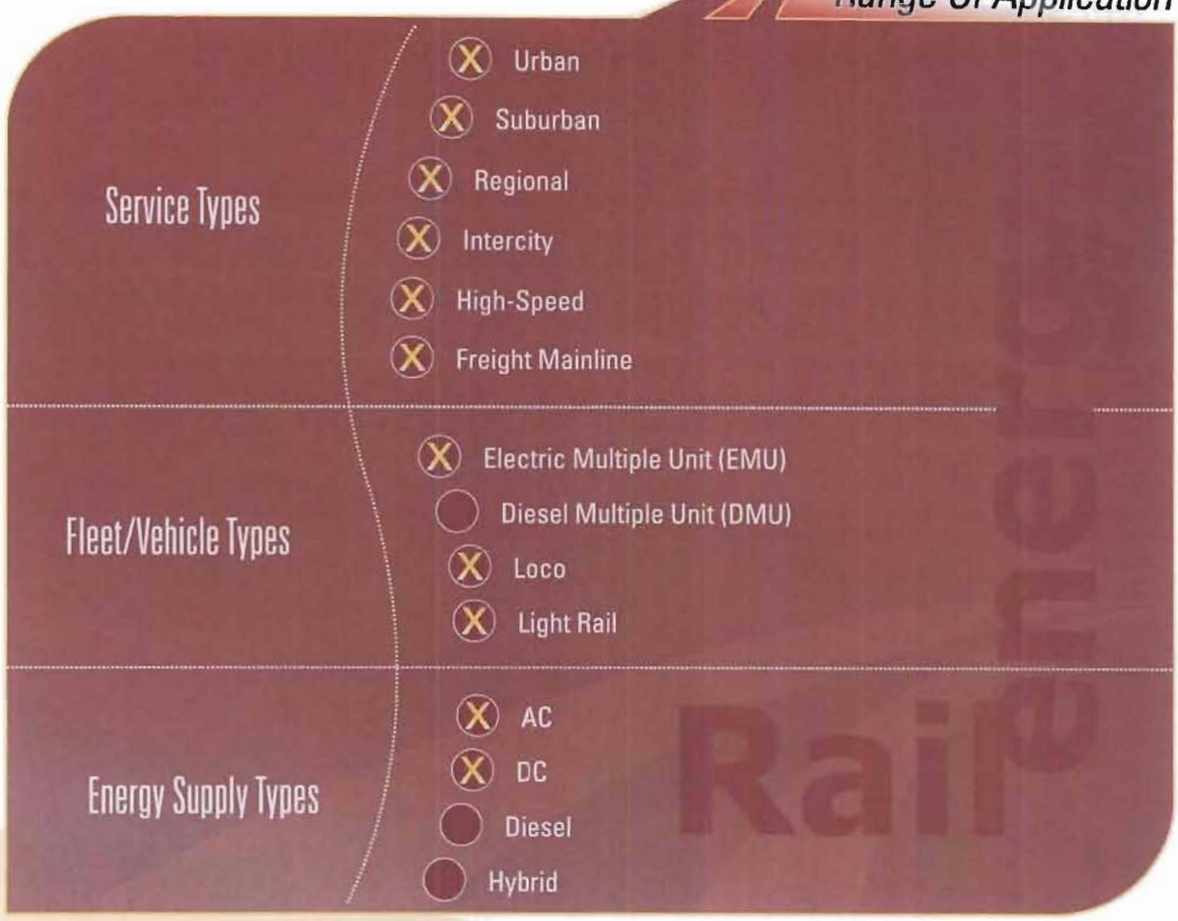
MV loads management					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	1-3%	2-4%	2-4%	Not applicable	4-7%
DC 3 kV	1-3%	2-4%	2-7%	2-4%	4-7%
AC 15 kV 16,7 Hz	1-3%	2-4%	2-4%	2-4%	4-7%
AC 25 kV 50 Hz	1-3%	2-4%	2-4%	2-4%	4-7%
Technology notes	Optimized management of MV (Medium Voltage) loads for cooling systems. When the maximum cooling performance are not requested, fans and pumps can operate at reduced speed or turned off in order to reduce the energy consumption and the environmental impact (reduction of noise, dust hoisting, ventilation channels clogging in case of snow).				
Baseline technology	The normal MV loads work at maximum speed without any kind of management.				

Advantages of the new technology

The benefits of this technology are:

- energy saving and
- reduced environmental impact (reduction in noise, blowing up dust, ventilation channel clogging during snowy conditions).

Range Of Application



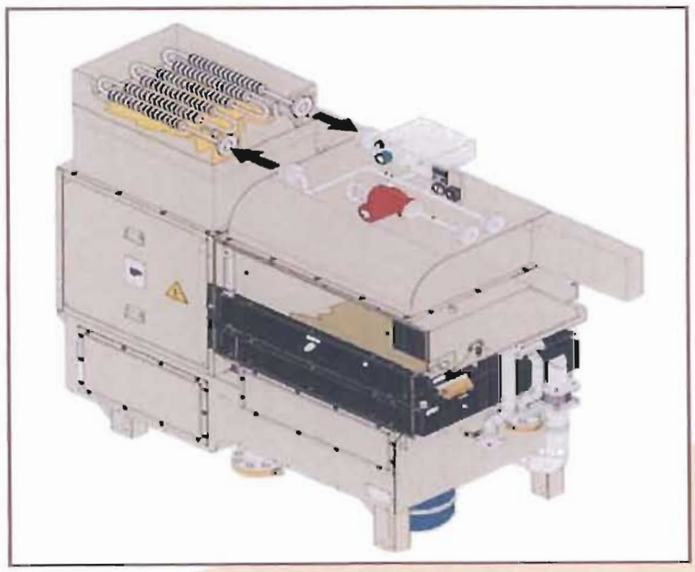
XVIII. Reuse of converter energy loss

Reuse of waste energy for the reduction of auxiliary consumption

Technology description

Energy produced through the operation of power and auxiliary converters, braking rheostat, main transformer and inductors is dispersed into the surrounding environment using cooling fluids: air, water and oil. The goal of this research was to recover part of this waste energy to reuse it in the vehicle. On top of the air outlet channel, a diathermic oil heat exchanger has been installed. The heat from the waste hot air is transferred to the finned tubes and then to the oil.

A hydraulic system circulates and controls the diathermic oil to enable heat recovery.

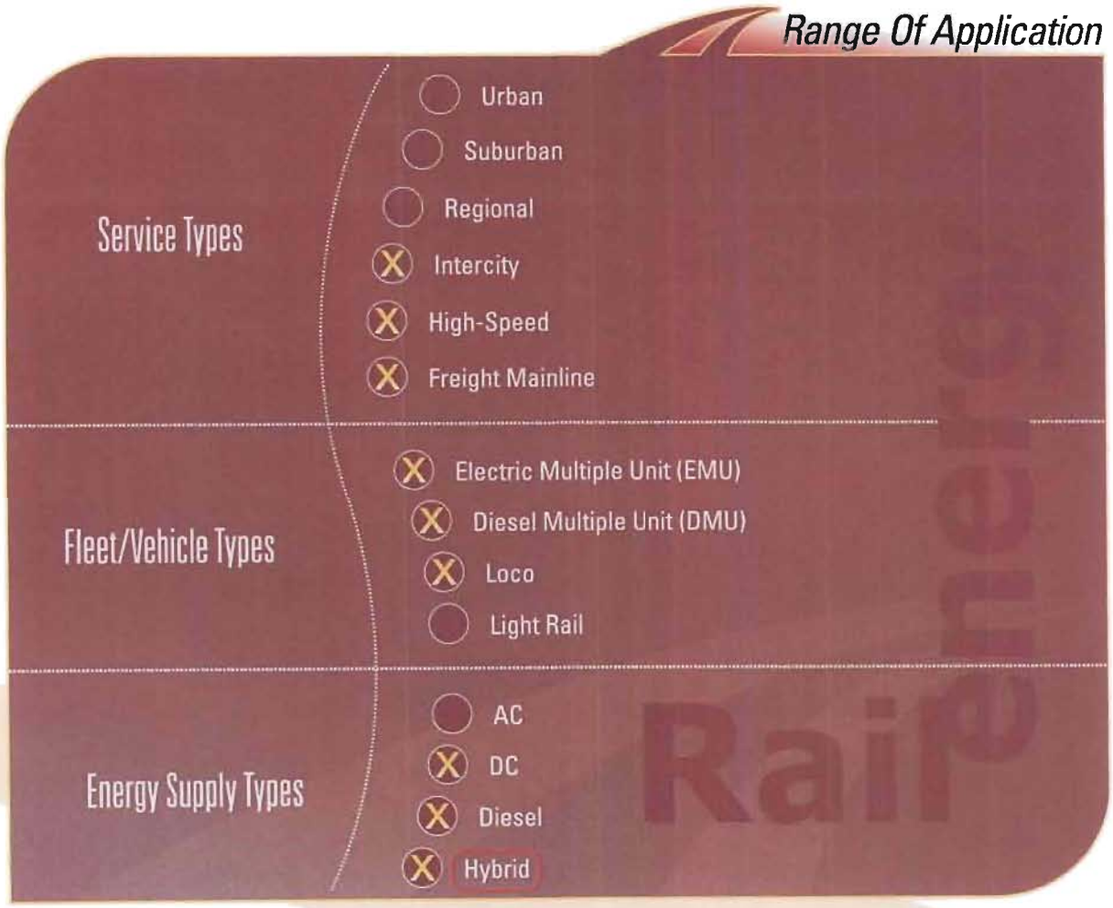


Energy saving potential

Reuse of converters' energy losses					
	Energy saving potentials				
Service type / Energy supply type	suburban	regional	intercity	high-speed	freight mainline
DC 1,5 kV	0,5-1,5%	0,5-1,5%	0,5-1,5%	Not applicable	0,5-1,0%
DC 3 kV	0,5-1,5%	0,5-1,5%	0,5-1,5%	0,5-1,5%	0,5-1,0%
Technology notes	Part of the waste energy produced by operation of power and auxiliary converters, braking rheostat, main transformer and inductors can be recovered for a possible reuse on the vehicle, by means of a diathermic oil heat exchange. An hydraulic system provides to the circulation and control of the diathermic oil for the heat recovery. Higher saving potential is expected for EMU towards Loco, because of an higher reuse of waste energy for coaches heating/cooling.				
Baseline technology	The whole energy produced by operation of power and auxiliary converters, braking rheostat, main transformer and inductors is dissipated in the external ambient without any kind of recovery system.				

Advantages of the new technology

Lower power absorption of auxiliary converters can be achieved by reusing the recovered energy for heating or cooling.



Notes



Railenergy



the best of Railenergy

SIXTH FRAMEWORK
PROGRAMME

Positioning Railenergy in the European research context

The Railenergy project is first and foremost an integrated project, providing a joint platform of understanding amongst the main industrial stakeholders. The project success is dependant on interaction with other major projects that influences the energy consumption or the generic design of the railway system. Projects that Railenergy is coordinating formal or informal with:,

- Modtrain, FP6 project, (www.modtrain.com), modular train concepts for European standardisation and cross acceptance of rolling stock and interoperable infrastructure systems
- Modurban, FP6 project, (www.modurban.org) - modenergy package
- Railway energy billing, UIC project (www.uic.org search under projects)
- Trainer, EU project "TRAining programmes to INcrease Energy-efficiency by Railways" (www.iee-trainer.eu)
- Several railway company projects on energy efficiency or energy economy.

Contact us!

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Partners

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