TRANSPORT INDUSTRIAL-ACADEMIC PARTNERSHIP AS A KEY SUCCESS FACTOR OF INNOVATION

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ABSTRACT

The author examines cooperation of large companies of the railway industry and universities in R&D, its contribution to innovative development of railway industry within a wider context of the increasing role of transport technologies in meeting challenges of globalization. Forms of corporate innovation process, participation in international research programs, including EU funded projects, interaction with universities, particularly with MIIT are analyzed at the example of the Alstom Group. The article in view of innovative achievements, which are key for rail transport, gives examples of technical results of the implementation of environmentally friendly and high-tech developments in the field of energy efficiency, ergonomics and qualitative improvement of the high-speed rolling stock.

Key words: *university, transport, partnership, innovation, research, intellectual property, human capital, energy efficiency, rolling stock, high speed rail.*

Background. *Worldwide demand for mobility is growing steadily as result of demographic changes, urbanization, economic trends, and globalization of economic links. Between now and 2050, the worldwide population is expected to reach 9 billion inhabitants, while 85% of that growth will account for developing countries; the part of urban population will pass from 50% to 70%; passenger flows will triple; power input will considerably increase [2]. In this regard, innovative transport technologies are in greater demand as they are destined to find optimum solutions meeting new challenges. Accordingly, considerable part of responsibility will lie on manufacturers of transport and transportation equipment, thus compelling those companies to interact with research and academic organizations.*

The division Alstom Transport that makes part of the Alstom Group, being one of the world's biggest manufacturers of transport equipment, present almost world-wide, is consistent in developing and implementing innovative solutions. The organization of innovative activities in different segments, comprising transport one, is an example of a lean design of corporate relations of business and academic structures, pursuing in particular the objective of sustainable development of the Group.

Objective. *The article is purposed to analyze best practices of interaction of business and academic organizations, aimed to create cooperative innovative environment, primarily in relation to rail industry, see its contribution to sustainable development, and to suggest forms of cooperation which can be widely spread while designing business-academic partnerships. The author offers examples of different forms of structuring of bilateral and multilateral links, as well as of implementation of results of innovative researches.*

Methods. *The author uses fact, comparative, engineering analysis, description method.*

Results.

Organization of research

The spectrum of expertise that a successful manufacturing company has to encompass is wide. In transport and transportation industry it covers materials science, traction motors, power electronics, enhanced aerodynamics features, noise & vibrations reduction, electromagnetic compatibility new information and communication technology, signaling systems, systems of passenger information, rolling stock maintenance, industrial design and aesthetics, human-machine interaction, qualitative and quantitative understanding and assessment of passenger comfort.

Considering innovation as a top priority, the Alstom Group is committed to research and development. In 2013 more than 10.000 employees were engaged in research and development (R&D) globally and Alstom invested more than 700 Million EUR in the R&D activities. Besides, each development of Alstom Transport is subject to testing with mandatory participation of research laboratories and academia.

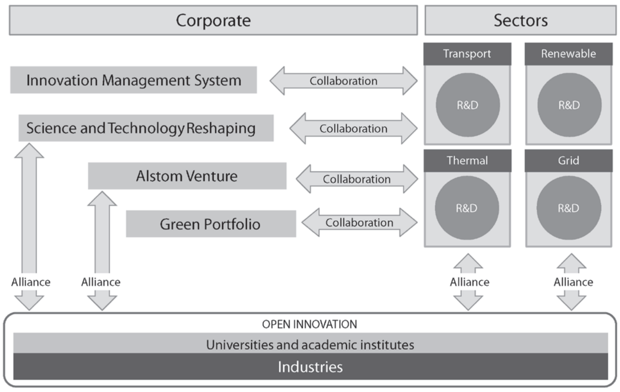
Modern state of the art intellectual property right (IPR) management system is one of the key aspects to secure the future income of the company and to inspire innovation [3]. This aspect plays a vital role in innovation cooperation with other industrial partners, laboratories and universities, but also allows keeping competitive environment and securing leadership in the market. The participation of the engineering team as patent owners in the long term business success of the patent and secures their continuous commitment to strive for more engagement and self-development in the interest of the company.

The Alstom Group has registered more than 12 000 patents and has published more than 400 scientific articles, including in Russia, and more than 1000 references could be found on innovation at Alstom Group.

However, considering the very wide range of expertise and/or knowledge that a manufacturing company must master, it is therefore evident that the industry either any company cannot invest in terms of R&D activities into all promising or highly demanded fields.

The manufacturer's main task is not to carry out research but to deliver high quality products to keep ahead of competition for which innovation is a priority factor but not the only one. Therefore it is important for the industry to resort to other extra-corporate sources of innovation, to consider and promote implementation of new ideas popping up in universities, research laboratories, start-up companies, newly born companies, and small and medium enterprises. It is our interest that those ideas are being developed up to the level of prototype or as a product in other sectors. We have continuously to search and scout for new solutions and young talents within scientific and education institutions.

[1] MIR Initiative is a project dedicated to creation of transport corridors, integration technology and development of mobility in the region METR (Middle East, Europe, Turkey, Russia) [1].



Pic. 1. Common innovative police of the Alstom Group.

Practices of implementation of cooperation

Alstom Transport pays special attention to partnership with research and educational institutions. More than 180 partnership agreements have been signed with universities and research centers in 20 countries, significant number of contracts are concluded, plentiful of research projects are implemented jointly with scientific laboratories.

Such cooperation is part of Alstom strategic program that includes venture capital investment in innovation projects (pic. 1). The efficacy of that form of interaction has been confirmed by proper corporate experience, as well as by numerous studies [see, e. g. 4]. In 2013 more than 500 innovate projects from 31 countries were applying for the yearly Innovation award of Alstom.

Generally there are different kinds of implementation of cooperative research projects:

• A company identifies a domain in which it has to beef up its expertise and funds future researcher who is going to work part time in the academic laboratory as well as at the industrial site on a subject decided by the business partner;

• A company launches a 3–5-year research project for which the participation of an academic laboratory along with expertise / knowledge of its staff is necessary because they don't exist within the company. Partnership is shaped between collaborative parties sharing their objectives and resources;

• In order to boost cooperation between industry and academia, several countries have established research programs providing for annual calls for proposals;

• There are intergovernmental international projects, including EU projects, which represent another kind of partnership of the industry, applied sciences› research centers.

Here are the following examples of multilateral EU projects involving Alstom:

• DYNOTRAIN – dynamics of rail rolling stock;

• PANTOTRAIN – interaction between contact catenary and pantograph;

• AEROTRAIN – AEROdynamics Total Regulatory Acceptance for the Interoperable Network [5];

• ACOUTRAIN – virtual certification of acoustic performance for freight and passenger trains [6];

• EUREMCO – electromagnetic compatibility within European railway network [7].

The above mentioned R&D projects, comprising those finalized recently, constitute excellent examples of partnership of rail industry and of educational institutions.

Another example is HORIZON 2020 which is the EU Framework Programme for research and innovation facilitating the cooperation between industry and academia. It covers seven years period (2014 to 2020) and has over €80 billion of funding available, and consequently will attract additional private investment. Its announced target is to promote and support more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market [8]. The support provided by the program is deemed to enable transport business as well as other industries to couple research and innovation, to further develop the European Research Area, to implement Innovation Union as Europe 2020 flagship initiative, and secure the global competitiveness of the European Union.

At national bilateral level in France Alstom has established close cooperation with a number of academic and research institutions of renown/ They are e. g. ENSAM (École Nationale Supérieure des Arts et Métiers), University of Valenciennes and Hainaut-Cambrésis (Université de Valenciennes et du Hainaut-Cambrésis, UVHC), IFFSTAR (Institut français des sciences et technologies des transports / the French institute of science and technology for transport, development and networks). The IFFSTAR, placed among most prominent French organizations in the fields of transport, infrastructure, natural hazards and urban issues, is a public institution of a scientific and technical nature, born on January 1st 2011, from the merger of INRETS and LCPC, acts under the joint supervision of the ministry of ecology, sustainable development and energy and the ministry of higher education and research.

In a more detailed manner multilateral cooperation at national French level can be shown at the example of participation of Alstom as one of partner enterprises in founding of Railenium, which is a technological research institute in the field of rail infrastructure. Among other partner enterprises were Bouygues TP, Eurotunnel, RFF (now infrastructure division of the SNCF), Vossloh-Cogifer. Poles of competitiveness are represented by Pole I-Trans (pôle de compétitivité pour les transports durables). Among partner research and educational organizations there are the IFFSTAR, University Lille 1, Technological University of Compiègne, University of Valenciennes and Hainaut-Cambrésis etc.

2009–2011: first version of HESOP

priority given to optimization of operating costs – double convertor - water-cooling

- ✓ recovery of the energy which is usually lost ;
- ✓ high quality of power;
- ✓ energy optimization continues.

2012-2013: new version of HESOP

priority given to optimization of operating costs and capital costs – single convertor with transformer IGBT – air cooling

- ✓ reduced number of substations;
- ✓ lowered environmental impact, diminution of equipment and devices at substations.

Pic. 2. Stages of HESOP developments.

Technological research institutes (Instituts de recherche technologique, IRT) are financed from public funds in the framework of the program of future investments (large-scale government loan, announced in 2010). Railenium is one among a number of that function as partnerships of the industry, regional councils, poles of competitiveness, research and academic institutions. Main targets of the Railenium are as follows: to enhance operation features of rail infrastructure (extension of track lifespan by 30%, of traffic capacity by 20%), as well as to promote implementation of innovations. Railenium will be structured around main campus at Valenciennes and Aulnoye-Aymeries – Bachant and two secondary campuses Lille-Villeneuve-d'Ascq and Compiègne [see, e. g., 9].

On the whole Alstom is involved in R&D partnership and contributes to 7 «competitiveness clusters» (out of 71 at a national level) which involve higher education and public research establishments, other companies and large industrial groups [10]. For instance in the framework of I-TRANS activities Alstom Transport leads three main projects: ULTIMAT (innovative use of new material in railway construction), ULTIMAT (innovative use of new material in railway construction), CEMRAIL (electro-magnetic compatibility in rail) and INOCAP (friction materials for pantograph-catenary) [10].

Among previously finalized projects the STEEM (Système de Tramway à Efficacité Energétique Maximisé or maximised energy efficiency tramway system) project could be mentioned. The STEEM project was developed in conjunction with the RATP and is based on an integrated energy storage solution. The system provides tramways with a high level of energy autonomy by enabling them to run without catenary power, be more effectively integrated into the urban environment and use less energy. In practical terms, supercapacitors were installed in a box on the roof of the tramset. The solution was tested on one of the 21 Citadis tramsets over a period of more than a year, from May 2009 to September 2010 [11].

Partnership with MIIT University

In Russia the Alstom Group started closer partner cooperation with Moscow State Railway Engineering University (MIIT) and signed a cooperation memorandum in March 2014. Besides other forms of interaction, the company is supporting the railway education with a series of lectures delivered by corporate experts in 2014 and continued in 2015.

From 2015 the MIIT students are offered practical studies in Alstom Transport Rus. This is a good opportunity future rail engineers and experts to improve international expertise and knowhow, and to have an insight in Russian and global operations of Alstom.

The company is considering using the excellent engineering base and expertise of MIIT increasingly to continue cooperation in education, training and research. Alstom together with French partners including universities and research centers are developing next steps to more tightened partnership which has so fruitful started.

Key vectors of innovative policy

Multilateral cooperation of Alstom with research and academic organizations resulted in innovations, implemented in manufacturing of rolling stock and divers types of transport equipment in many countries. The examples that follow are classified by priority fields of research and implementation of achieved results and innovations.

<u>*Energy efficiency and ecological friendliness*</u>

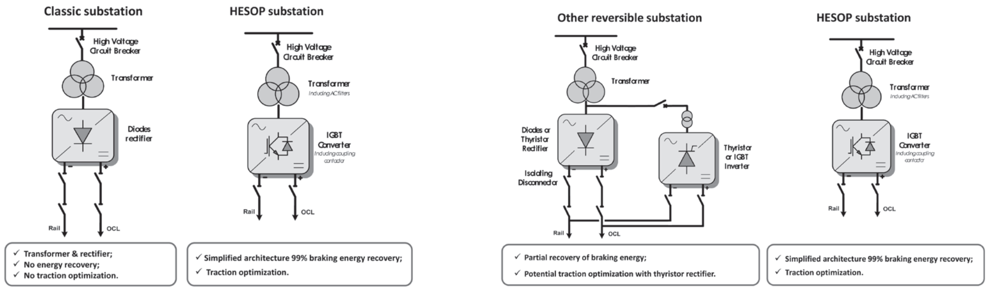
Global economic trends and limited availability of natural resources urge the transport industry to think out of the box and test new technologies. Under those circumstances energy efficiency and ecological sustainability take the key role in engineering ecologically friendly solutions. It is especially true for railways, as they are most efficient for transport corridors, linking cities, countries and regions [1], as well as most suitable means of transportation in comparison to aviation and road traffic.

To reach those objectives it is not thinkable to avoid large-scale investment in R&D. European manufacturers of the sector, e. g., have already tailor-made solution for railways which is SHIFT2RAIL project, targeting to drive innovations at the railways [12].

The main objectives comprise:

1) improving quality of rail services by increasing reliability and punctuality by as much as 50%;

2) reducing congestion and CO2 emissions by doubling railway capacity;



A) B)

Pic. 3. Differences in traditional substation's and HESOP architecture.

FUNCTIONS	Rectifier/ convertor with transformer IGBT HESOP	Thyristor rectifier	Diode rectifier	Transformer IGBT/ thyristor inverter	Storage
Voltage regulation	✓	✓	✗	✗	✓ (limited)
Harmonic filtering	✓	✗	✗	✓ (IGBT only)	✗
Smoothing power peaks	✓	—	✗	—	—
AC voltage changes compensation	✓	—	✗	—	—
Braking energy recovery	✓	✗	✗	—	—
Priority to natural exchanging between trains	▯▯▯▯▯▯▯▯▯▯	—	—	▯▯▯▯▯▯▯▯▮▮	▯▯▯▮▮▮▮▮▮▮
No need for regenerative resistor	✓	—	—	—	✗
Reducing of heat emissions	▯▯▯▯▯▯▯▯▯▯	—	—	▯▯▯▯▯▯▯▯▮▮	▯▯▯▮▮▮▮▮▮▮
Traction functions	✓ (100%)	—	—	✗	✗ (limited)
PREFERENCES					
Optimization of traction power	▯▯▯▯▯▯▯▯▯▯	▯▯▯▯▯▯▯▮▮▮	✗	—	—
Energy saving (peak loading + consumption)	▯▯▯▯▯▯▯▯▯▯	▯▯▯▯▯▯▯▮▮▮	▯▯▯▮▮▮▮▮▮▮	—	—
Optimization of capital costs regarding a substation	▯▯▯▯▯▯▯▮▮▮	▯▯▯▯▯▯▯▮▮▮	▯▯▯▯▯▯▯▯▯▯	—	—
Optimization of capital costs regarding all the line	▯▯▯▯▯▯▯▯▯▯	▯▯▯▯▯▯▯▮▮▮	▯▯▯▯▯▯▯▯▯▯	—	—
Consumption/recovery of the energy	▯▯▯▯▯▯▯▯▯▯	—	—	▯▯▯▯▯▯▯▯▮▮	▯▯▯▮▮▮▮▮▮▮
Safety factor	✓	—	—	✓	✗

Pic. 4. Comparative features of HESOP.

3) cutting the costs of infrastructure and rolling stock by up to half;

4) retaining Europe's leadership in the global rail market.

Such programs can be an excellent show case for other countries including Russia how to secure competitiveness of the industries and academics by staying innovative in the domestic but also in the export market.

Alstom Transport, guided by commitment to socially responsible business model and sustainable development, anticipates new environmental and social challenges of mobility and consequently sets its priorities:

- *further developing of ecologically reliable solutions for high environmental performance in rolling-stock, smart railways systems and value-added services;*
- *ecological priority in all areas of corporate activities;*
- *strengthening of collaboration with customers, suppliers and other business partners based on sustainability factors.*

Alstom Transport is implementing principles of Ecodesign which aims at improving the environmental performance of our solutions over their entire lifecycle. All product platforms are designed with respect to their enhanced environmental performance which focuses on:

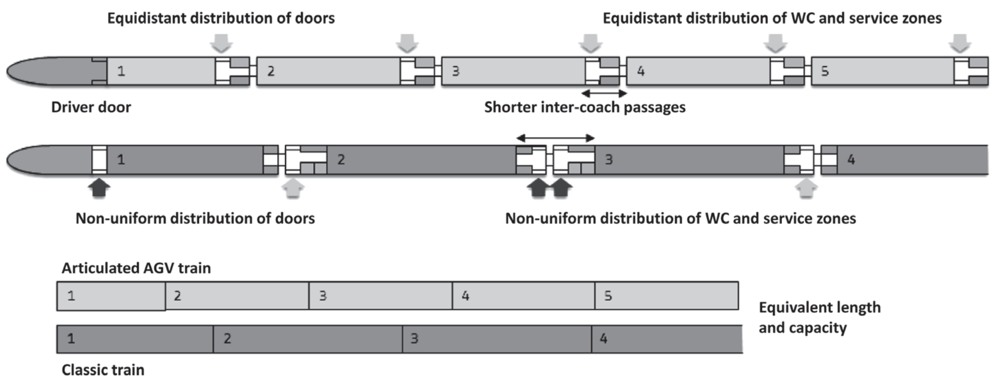
- *Energy efficiency;*
- *Use of clean, recyclable or natural materials;*
- *Noise and vibrations reduction;*
- *Air emissions reduction;*
- *And/or easy end-of-life management.*

Implementation passes in particularly through use of biodegradable materials, biologically clean materials manufactured from renewable sources (e. g. waterborne paints), removal of hazardous substances from liquids, oils etc. Ecological environment is also provided for creating labor safe conditions for staff and contractors, by reducing detrimental effects of production sites (e. g. by implementing programs of waste processing, certification under ISO 14001).

The answers to the questions of tomorrow pass by creating interconnected urban transport, overcom-

Train configuration		Train	Length (m)	Capacity	Max. capacity
300 km/h		AGV 7	132	245	312
300 km/h		AGV 8	149	321	378
360 km/h		AGV 11	200	455	510
360 km/h		AGV 14	252	593	654
Distance between the seats (mm)	First class			980	980
	Second class			920	900

Pic. 5. AGV configuration.



Pic. 6. Comparison of trains of classic and articulated architecture.

ing limits of speed, creating intelligent traffic systems [see, e. g., 13], and by converting usual city landscapes into the cities of future.

To cite a striking example of innovation with an accent on environment protection, it is possible to refer to HESOP (Harmonic and Energy Saving Optimizer) power reversible substation [14, 15], capable to recover energy of braking. The project has been stage-by-stage developed (pic. 2) and installed at Paris tram lines, in metro systems of London and Milan, will be implemented in the year to come for Ar Riyadh metro system and Milan tram routes.

From technical point of view HESOP is the newest reversible substation with all-in-one convertor for invertor and rectifier, compatible with DC of 600–1500 V and 900kW-4MW range. The system enables recovering of the energy at braking and has dynamic voltage regulation for optimization of power consumption in traction mode. The architecture of the model, its technical data, and operating features are shown in Pic. 3 and Pic. 4.

The substations installed in 2014 on the pilot site of Milan metro will undergo in 2015 a one-year testing period in order to validate the achievement of objectives in terms of environmental impact, which are:

– 15% reduction in train energy consumption through recovering of all the electrical braking energy; – maintaining priority to natural energy exchange between trains;

– 15% reduction in greenhouse gas emissions.

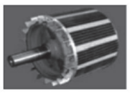
The HESOP project fully meets the European Commission's Life+ programme selection criteria [16]. It is worth noting that such a development has been reached due to the cooperation with universities/research institutes who considerably contributed in designing of HESOP substations.

High Speed Rail

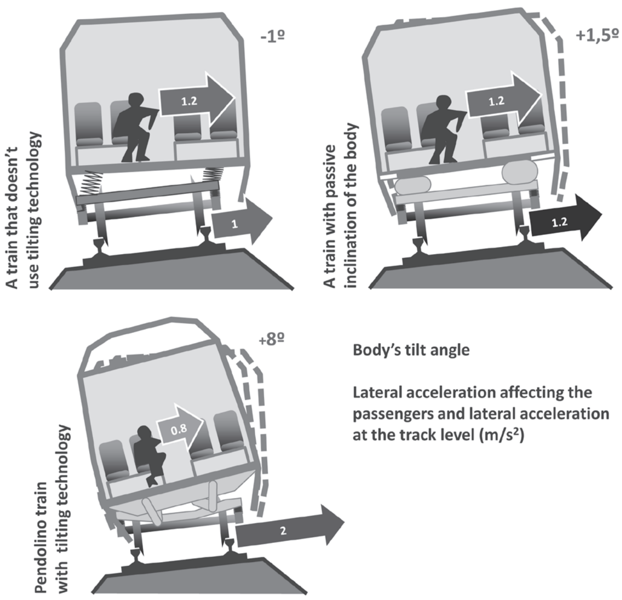
Furthermore the key flagship of Alstom Transport is the very high speed rolling stock development based on the TGV development [17]. During more than 30 years of fruitful activities Alstom together with SNCF obtained leadership in innovative manufacturing of most modern very high speed trains with the biggest fleet of more than 800 trains in daily operations.

High speed test jointly realized by French Railways SNCF, TGV manufacturer Alstom, and infrastructure owner Réseau Ferré de France[1] can be considered as index of success in the HSR sector and also as a driver for further innovation. The test was held with V150, a specially configured TGV high-speed train built in France. On April, 3, 2007 on an unopened section of the LGV Est between Strasbourg and Paris the train broke the world land speed record for conventional railed trains by reaching the speed of 574.8 kilometers per hour (357.2 mph), topping the previous record of 515.3 kilometers per hour (320.2 mph) set in 1990 [18]. Those tests were also

[1] Now the functions of RFF are delegated to SNCF Infra. – ed.note.

	1981	1989	1994	2004
	TGV Paris – Sud	TGV Atlantique	TGV Duplex	AGV
Motor type	DC	Synchronous with phase-wound rotor	Asynchronous	Synchronous with permanent magnets
Capacity	535	ISO	1020	720
Weight	1560	1525	1260	720
Weight to power ratio	2,9	1,35	1,23	1
				

Pic. 7. Evolution of traction motors.



Pic. 8. Forces affecting a passenger during the travel.

realized in close cooperation with laboratories and academia. Besides, this test was the base for components (as e. g. the Permanent Magnetic Motor (PMM)) and for a new generation of very high speed train AGV. Today AGV is operated by the first private operator NTV on the Italian very high speed network.

The AGV is based on three main technologies which have been combined for the first time: flexibility of the platform, including articulated carriage architecture; a distributed traction drive system; and synchronous permanent magnet motors.

<u>Flexibility of the platform</u>

The flexibility of configuration has become a decisive factor for AGV. It is the only one high speed train, designed for international market as a whole, not tailored on the demand or according to specifications of a given operator.

Emergence of a unique platform presumes a wide choice depending in specific requirements of each operator:

– possibility to form a train of any length thanks to modular system of distributed tractive power, allowing to freely increase or reduce the number of coaches (pic. 5);

– different combinations of maximum speed and starting dynamics thanks again to distributed tractive power and synchronous traction permanent magnet motors;

– possibility to operate the train on rail mainlines supplied with any kind of voltage of overhead catenary and specific power up to 22,2 kW/t (it can be intended for single- either for multisystem power supply);

– unification of main units, comprising driver's controller, bogies, undercarriage equipment, taking into account divers signaling systems.

The notion of flexibility can be applied not only to technical parameters of the train, but to ergonomic features as well:

– concept of interior arrangement of a train admits unique decisions as for interior of every passenger cabin of the train;

– articulated architecture allows placing of doors of coaches at even distance from each other without reducing their number as compared to trains of «classic» architecture, ensuring thus optimum passenger capacity, convenient access to the coaches, comfort of passengers (a door is

located not far than at 9 m from any point in a coach);

– equidistant location of platforms and service zones allows to improve distribution of space on board of the AGV coaches, as opposed to popular misconception that big number of passages results in reduced usable space (comparison of passenger capacity of the trains of «classic» and articulated architecture is shown in Pic. 6);

– designing of all the coaches as of hollow pipes allows to allocate main technical equipment outside passenger areas, using undercarriage or underroof space;

– modular architecture and flexible approach to lighting facilitate creating divers interiors just in one and the same train, and this flexibility can be maintained during all lifespan of the train (possibility to change location of seats, design of interior panels, mode and elements of lighting etc).

Permanent magnet motors

Motors developed by Alstom have high specific power (1 kW/kg) and lower specific power consumption. As compared to classic asynchronous traction gears for high speed trains innovative technology of synchronous PMM allowed to improve carriage architecture and to optimize mechanism of electric power transmission, resulting in enhanced reliability and reduced maintenance costs. Evolution of motors corresponding to Alstom high speed trains of all generations is shown in Pic. 7.

Trains with tilting technology

Clients often need to increase traffic speed in between cities without important investment in infrastructure. Tilting technology implemented in the trains of Pendolino platform is thus a unique solution. Tilting system permits to tilt the carriage and therefore to operate the electric train at speeds of up to 250 km/h on conventional railways with curves of major radius. In other words Alstom Tiltronix technology combines a device of active tilting, inclination of the body (8%) and a possibility thanks to previously described technology to pass curves faster by 30–35% as compared to analogic trains. The name «Pendolino» by the way comes from the Italian word «pendolo» which means pendulum. So it describes the capacity of carriages to incline in the turn with regard to vertical axis.

On November, 26, 2013 a Pendolino train, which was tested on the lines of Polish railways (PKP), renewed world record for speed trains on conventional lines by attaining the velocity of 293 km/h.

Pendolino trains have special, electronically controlled gears that tilt carriage's body just in curves. The technology enables also self-centering mode: when the body leaves tilting mode the pneumatic system complementarily centers the body with regard to the track axis. The Pic.8 illustrates the different forces that influence a passenger when a train uses tilting technology or it doesn't.

Four trains each consisting of seven Pendolino carriages has been operated in Russia on St.Petersburg – Helsinki line since December, 2010. The travel time consequently reduced from 5,5 to 3,5 hours. Besides it is still possible to save other 15 minutes without huge infrastructure investment.

Conclusions. *Transport industry will have a considerable impact on further developments if economic relations in globalized environment, will facilitate environmental protection, and promote technology innovation and research. Manufacturers of rolling stock and rail equipment will continuously considerably contribute to the achievement of those objectives. But in order to meet future demand for innovation, joint activities and partnership between academia and railway industry should be a must. Only well-arranged cooperation will secure the utmost result.*

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