Highgate Converter Station
A
Superfast HVDC Project

by

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Background

- Vermont Electric Power (VELCO) had a 150 MW share of Vermont Yankee Nuclear Power Plant.
- September 1985 the power plant was to commence refurbishment for a long period.
- VELCO needed to find reasonably priced replacement power and did so from Hydro Quebec, but very late.
- As the 60 Hz systems of Quebec and Vermont are not in synchronism a back-to-back HVDC station was needed.
- Lars Bergström was able to convince VELCO to accept ASEA as bidder.

Tender

- The request for proposal arrived via fax less than a week before tender submittal date.
- ASEA had made a few unsuccessful bids for 200 MW B2B stations and decided to bid a 200 MW station *in lieu* of 150 MW as to be able to use available prices and performance data for equipment from internal and external suppliers.
- Tender reports on general performance, audible noise, station losses etc were written as well as production of conceptual civil and electro-mechanical drawings etc.
- Gunnar Flisberg was granted a few hours extension of submittal time as to be able to make it to VELCO from the airport.

Contract

- ASEA was able to convince VELCO to accept the larger 200 MW station.
- ASEA was awarded a $20 million contract a week after tender submittal for take-over 17 months later.
- The contract was of type EPC including implementing, to a deforested area approximately 400 x 400 ft (120 x 120 m) in the hamlet of Highgate, VT, drainage, foundations, cable channels, conduits and all necessary equipment and buildings above ground plus perimeter fence as well as design, engineering, procurement, shipping, installation and commissioning of the finalized HVDC station.

Main data

- Bidding time: One week
- Contract award: April 1984
- Commercial operation: Sept 1985
- Delivery time: 17 months (the previously shortest took 24 months)
- Configuration: Back-to-Back (Line Commutated Converters, LCC)
- Power rating: 200 MW
- AC voltages: Hydro Quebec 120 kV and VELCO 115 kV
- DC voltage: 56 kV
- Short-circuit power ratio: 1:1 (grid:converter)

Project work

- No initial grace period, but head start right on.
- Very high emphasis on identifying and solving internal and external interface issues.
- Numerous design proposals, large and small, were sent via fax to VELCO consultant Teshmont of Winnipeg, MB with required response time of maximum two weeks.
- 24 kV CTs were bought from Ritz as ASEA department was unwilling to deliver documentation ahead of product delivery.
- Power and control cables manufactured according to American standards and AWG sizes, were bought from ASEA Kabel in Sweden at a significantly lower price.
- Electro-mechanical design performed by ASEA SVC department in Västerås.
- Recalculations showed need for smoothing reactor thus implemented.
- Recalculations showed need for higher valve price which was granted.
- Project valves by-passed production-planning engineers by far to meet delivery time.

Development

- It was decided to use totally new octuple valves utilizing new thyristors, type YST60 (60 cm^2 wafer), suspended from the ceiling like the quadruple valves of Pacific Intertie Upgrading.
- Optimizing resulted in 2 + 1 ea three-phase three-winding (3Ø 3W) converter transformers.
- ASEA's first 145 kV filter/shunt-bank circuit breakers with pre-insertion resistors to avoid high inrush currents. Nowadays mechanically staggered poles governed by adaptive-controlled Switchsync™ device are normally used for 145 kV breakers.
- Three-phase wall-mounted motor-operated grounding switches for the indoor converter-transformer bushings.

Highgate converter station – Satellite photo



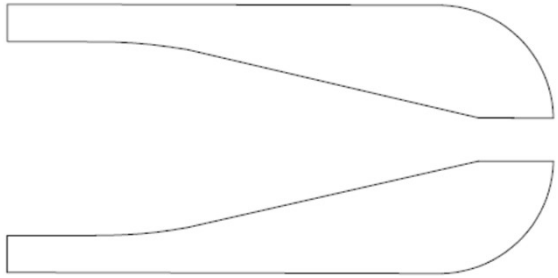
Technical challenges

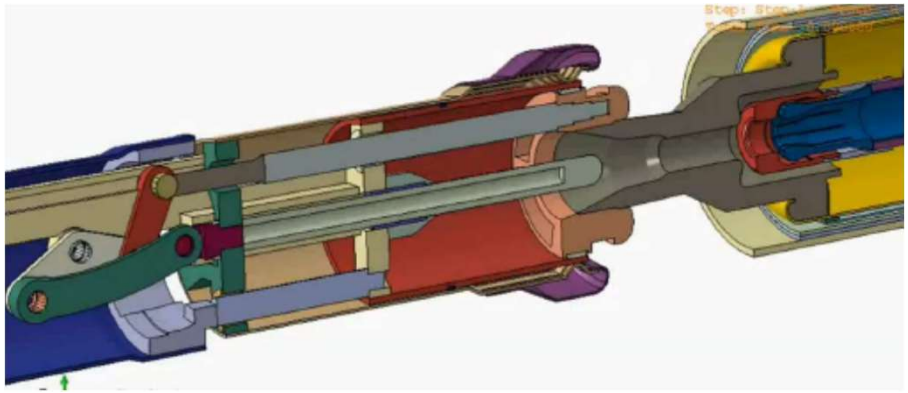
- Low short-circuit power ratio of incoming 120 kV line from Hydro Quebec and 115 kV line from VELCO resulting in:

    1. Actual grid to converter short-circuit power ratio of 1:1 vs normal > 2:1.
    2. Binary switching with filter/shunt-bank sizes of 20 and 10 MVAr amounting to 8 ea banks on each side.
    3. Line circuit breakers, HPL 245, equipped with “spittoon” nozzles to better withstand high transient recovery voltage, TRV.

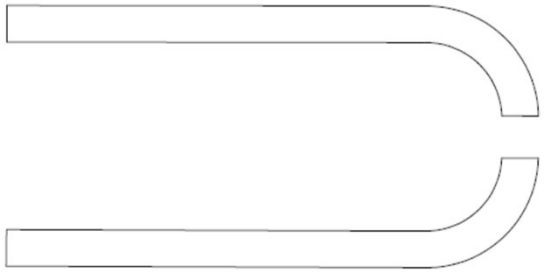
- Binary switching requiring circuit-breaker pre-insertion resistors.
- Very high voltage ratio of station service transformers, 250:1, made installation of surge capacitors needed on the 480 V side.

Circuit-breaker nozzles





‘Rocket nozzle’
Good for breaking high short-circuit currents and withstand moderate TRV.



‘Spittoon nozzle’
Good for withstanding high TRV but poor for breaking short-circuit currents.

Insurance and shipping



- Deregulation of freight insurance resulted in rate 1/3 of previous per ton.
- Ocean freight taking 2 weeks from Europe to Halifax, NS.
- Railroad freight from Halifax, NS to freight terminal in Montreal, QC.
- Motor freight, 2 h, from freight terminal to work site.
- Almost all goods were shipped in containers.
- For eventual on-site design alterations different sizes hot-dip galvanized steel beams and different sizes aluminum conductors were shipped.

Converter transformer shipping



Caboose was the last car in a railroad train and equipped with brakes for manual braking from the times when other cars had no brakes. Many years after each car got pneumatic brakes trade unions still insisted on having two members riding the caboose.

For the transportation of the converter transformers from Halifax, NS harbor to Montreal, QC, Ove Jansson checked the impact recorders, rewound their clock springs and supervised the trips with the caboose operators as the ASEA rider. Jansson later dressed and tested the transformers on site.

Open-top containers



Storage area at work site was very limited.

After first shipment only open-top containers with tarp roof were chosen to enable lifting goods directly from container to foundation.

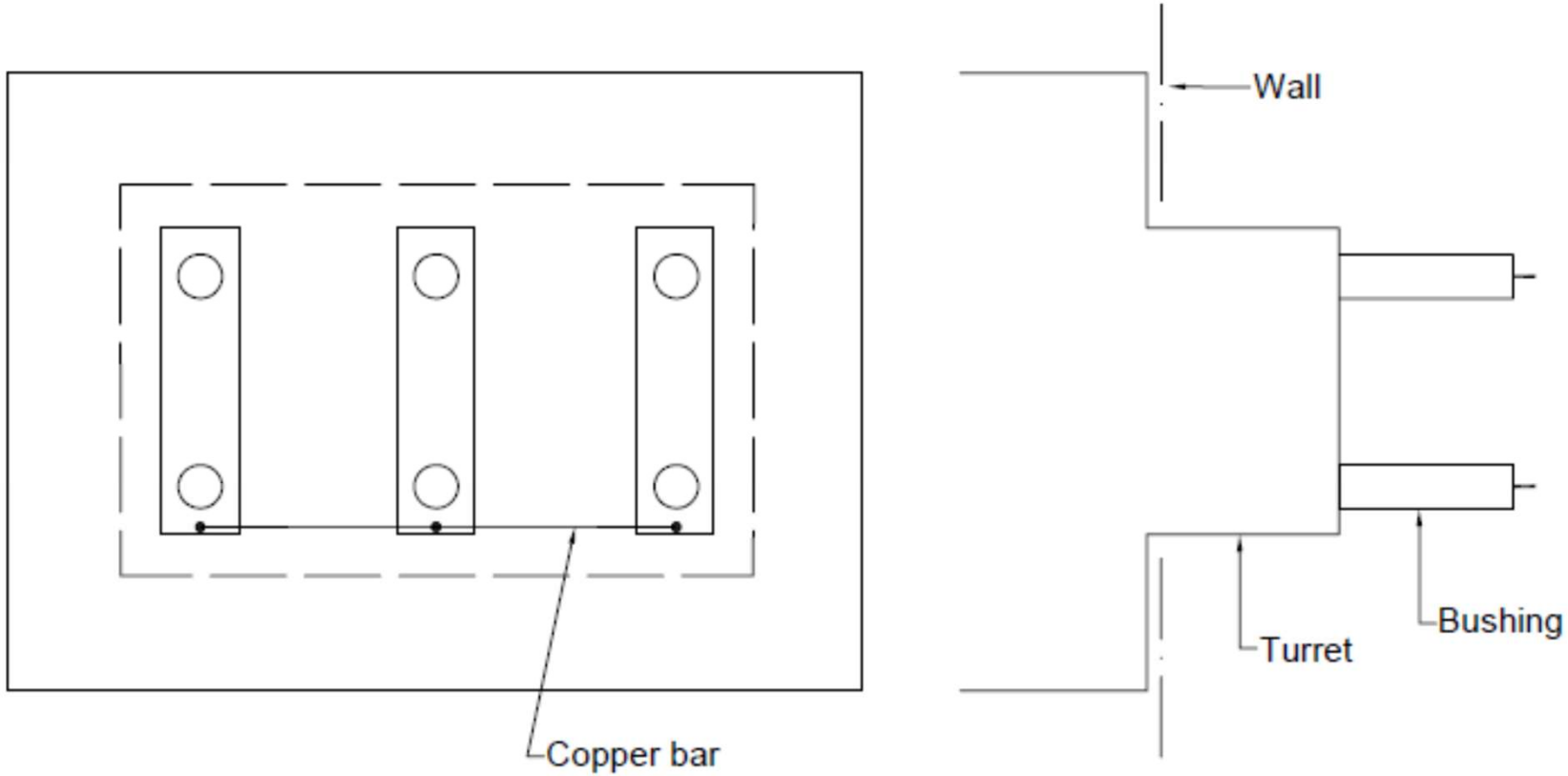
As the contents of each container was in the shipping manifest, only specific containers were called-off from the freight terminal on specific days.

Site work

- During excavation archeological findings after Native Americans delayed part of site work for some weeks.
- Sabotage by sawing off a thick bundle of cables to filter/shunt banks was solved by buying new cables from US manufacturer and install them in a couple of weeks.
- VELCO's president Jack Zuckernick decided late in the project to add to already conservatively designed 120/115 kV line breakers (HPL 245 with spittoon nozzle) yet another set in series on each side with the motivation: - I don't like to appear on the 6 pm TV news to tell why Vermont has had a blackout. That move made me well aware of how very expensive it is to change/add something during a running project.
- A station service transformer was accidentally dropped in harbor and was shipped back to Ludvika, repaired and equipped with OLTC before shipment to site.
- Transformer turrets in valve hall had to be potential bonded by means of copper bars after screens of cables to bushing capacitive taps were burned off due to vagabonding currents. Please see illustration on next slide!
- Protection against "ladder left behind" produced nuisance alarms.

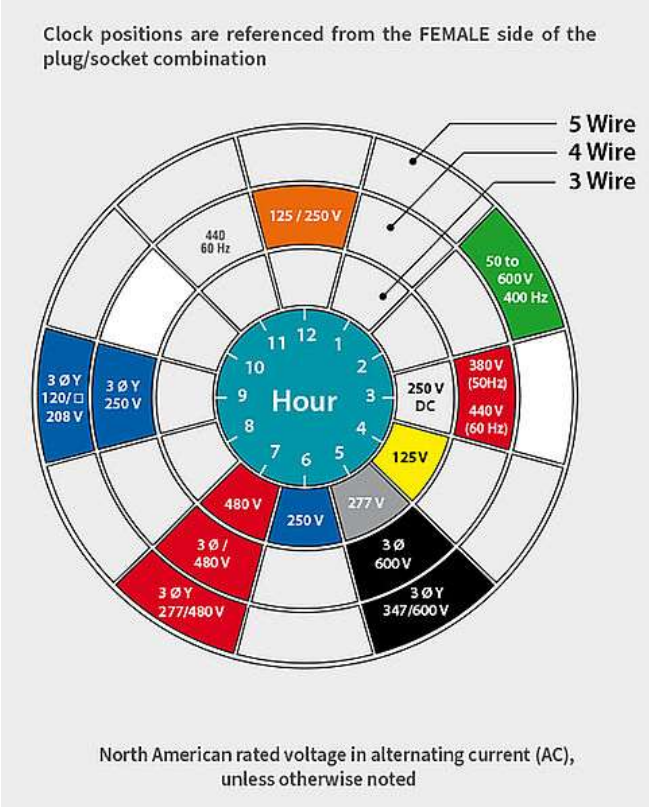
Illustration

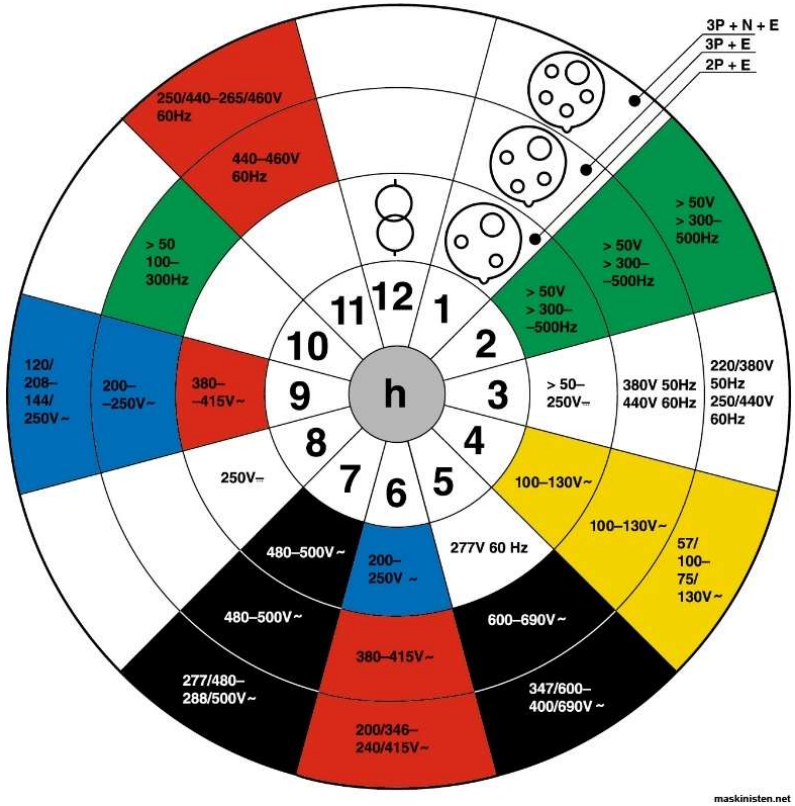
Converter transformer 3 Ø 3W



CEE power outlets

Probably the first HVDC station in North America utilizing international CEE power outlets a measure to better meet HSEQ criteria





Miscellaneous

- Top-brass managers visiting site were worried over slow progress when seeing only ground construction in place, but very pleased a few weeks later when steel supports and apparatus were erected.
- High emphasis were put on having valve hall and control/service building tight before winter sub-zero temp winds from Hudson Bay arrived and stayed. That enabled indoor installations under warm conditions, thus meeting HSEQ aspects.
- Client humbly asked if violating warranty if he installed knife switches for auxiliary power in mechanisms. ASEA said OK, if done after take-over.
- Despite putting documentation payment at 50 % of $150,000 contract for low-voltage switchgear it still ended up on the critical path.
- Highgate could have been a neat-looking station if only all insulators had been ANSI 70 light grey. I regret purchasing circuit breakers and transformers with brown-glazed porcelain.

Profitability

VELCO

- Contract for converter station: $20 million
- Transmission lines and breaker bays: $8 million
- Pay-back time: 8 months

ASEA

- Net-profit margin at order: 10 %
- Net-profit margin at commercial operation (*): 14 %

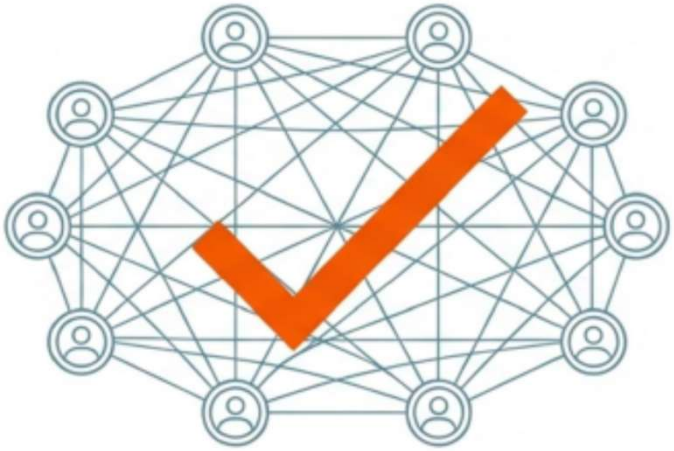
(*) despite added costs for smoothing reactor etc and thyristor valves

The impossible made possible due to:

- Trust-based leadership.
- Competent employees.
- Dedicated employees.
- Necessary power transmission disciplines; engineering, design, manufacturing and testing, located very close together in Ludvika.
- Manufacturing of the new thyristor valves by-passing the work of production-planning engineers to meet delivery time.

Illustration of the Ludvika Way at the time of the Highgate Converter Station

HVDC, Project-Driven Organization



The Ludvika Way

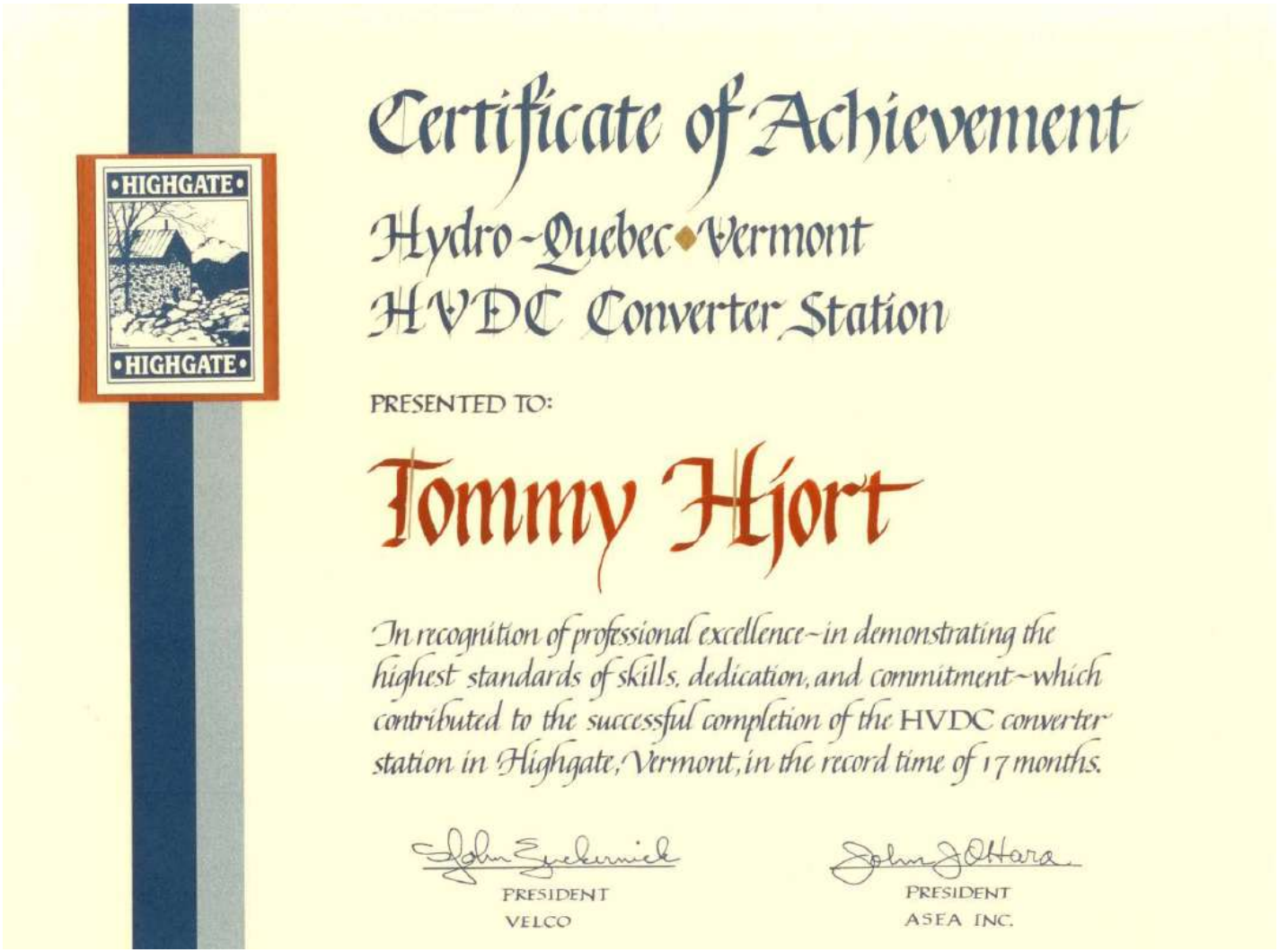
The Rule

Free Information Flow. Any individual can approach *any** expert directly to ask for help. No need to go manager-to-manager to allocate resources.

Impact

Status was derived from expertise, not title. If you didn't know the answer, you referred the question to someone who did, regardless of their rank.

Recognition of services rendered



Some people involved in the project

• Lars Bergström	Sales engineer
• Sten Bohlin	Tender responsible
• Kenneth Brunman	Electro-mechanical designer
• Stefan Elenius	Commissioning engineer
• Gunnar Flisberg	General sales manager
• Tommy Hjort	Lead engineer
• Ove Jansson	Supervisor, transformer erection
• Birger Jonsson	Commissioning engineer
• Torvald Lundström	Supervisor, civil construction
• Juha Mullo	Supervisor, valve-hall installations
• Thomas Nilsson	Supervisor, switchyard installations
• Kjell Svensson	Protection Coordination Engineer
• Svante Svensson	Commissioning engineer
• Leif Wilhelmsson	Project manager
• Urban Åström	Transformer designer (active part)