Effektiva tågsystem för godstransporter
- Underlagsrapport -

Dual system Locomotives for future rail freight operation

- Concept and preliminary ratings

Duolok för kombinerad el- och dieseldrift i framtida godstransportsystem

- Koncept och inledande prestanda beräkningar

Rapport 0506A

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1 Introduction

In the study on Efficient trains for future rail freight operation it has been observed that there are several advantages with having a universal locomotive capable of fulfilling different operational tasks[1].

The wagonload system of today in general requires double fleets of locomotives

- Terminal locomotives, normally with diesel engines, that are used mostly during daytime
- Main line locomotives, normally electrically fed, that are used mostly during nighttime.

The main drawbacks of the diesel locomotives used today for terminal operation are essentially

- Costs related to exchange of locomotives
- Low utilization due to the above mentioned fact that two fleets of locomotives are required
- Environmental issues concerning the use of diesel engines

The main drawback of the electrical main line locomotives is of course that their operation is limited to electrified lines.

A universal locomotive is also beneficial for system freight trains. System freight trains generally carries one load and operates at relatively long distances. A Dual system locomotive would make the use of locomotives more efficient since fewer units are required. It also shortens the transport time since no exchanges of locomotives are necessary.

The basic idea with this report is to describe the concept of a universal locomotive that combines the two tasks described above. Preliminary estimations of ratings and performance have been done. The locomotive is referred to as a Dual system locomotive.

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[1] During 2004 a new project has been initiated by TFK and the KTH Railway Group exploring more in detail the performance and design of a Dual system locomotive.

1.1 Objectives, market and target price

The objectives of the Dual system locomotive are

- *To collect freight wagons on industrial track*s. Normally a relatively moderate performance is required since the number of wagons is low. In general diesel operation is used.
- *Main line operation*. In general the locomotives are operating with electrical power from the over-head catenary system. The power level must be high enough to allow for reasonable speed and acceleration not to put restrictions on the capacity of the line for passenger services.
- *Shunting* that requires high tractive effort and low speed.

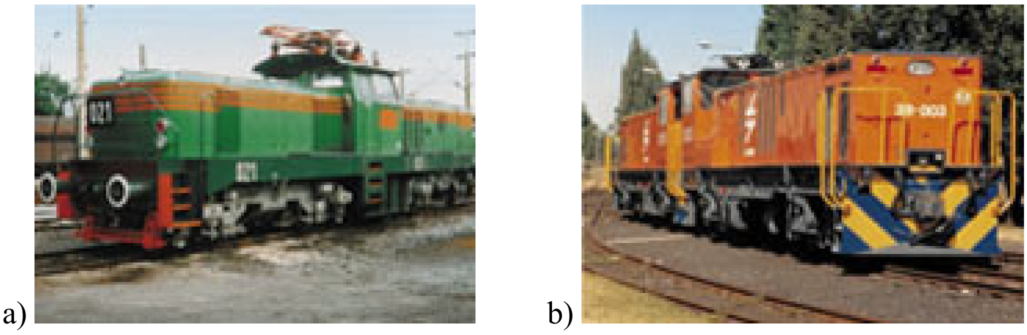
The locomotive must be able to operate 24 hour a day for different purposes. In that way the time when the locomotive is operating and "paying back" increases significantly in comparison to existing vehicles that normally have characteristics that limit their operation to either main line service or shunting.

To be competitive to alternative solutions a Dual system locomotive must have an attractive price at least from the point of view that it is a universal locomotive replacing several different locomotives thus being a more efficient solution. It is at this early stage not possible to give an accurate estimation of the price level but the interval 15-20 MSEK per locomotive might be realistic as an initial target price.

1.2 Dual locomotives in operation

1.2.1 Dual locomotives with electric supply and diesel engines

Today dual-mode locomotives are not very common. Figure 1. shows two examples of Dual-system locomotives delivered during the nineties.



a) b)

Figure 1.1 Dual Mode locomotives, a*) ED 1600 for RAG Bahn- und Hafenbetriebe, Germany, b) Class 38 for South African Railways [Siemens web-pages]*

In recent years Siemens has built two locomotives for the RAG Bahn- und Hafenbetriebe, Germany. The ED1600 type was originally designed for operation on line voltage and battery but has later been converted to a diesel engine/line voltage dual system locomotive. The reason behind the conversion was to increase the power during electric mode operation. The locos are claimed to haul trailing loads up to 2000 metric tons at a speed of 60 km/h and trailing loads up to 1000 metric tons at 80 km/h[2]. Its ratings are given in Table 1.1.

At about the same time 50 locomotives for 3 kV dc and diesel mode operation were delivered to the South African Railways (class 38). These locos have a narrow gauge[3] and are designed for a higher speed, 100 km/h. The ratings in Table 1.2 show that the diesel power installed is higher making the locomotives able of more general services compared with the ED 1600 of RAG. The characteristics of the class 38 have similarities to those assumed in this study.

Table 1.1 Ratings for the Dual-system locomotive ED 1600 of RAG

Year	1992
Diesel engine power	560 [kW]
Continuous rating at 15 kV, 16.7 Hz	1600 [kW]
Continuous rating diesel engine mode	425 [kW]
Starting tractive effort	360 [kN]
Maximum speed	80 [km/h]
Weight	88 [t]

Table 1.2 Ratings for the Dual-system locomotive class 38 for South African Railways

Year	1992/1994
Diesel engine power	780 [kW]
Continuous rating at 3 kV dc	1500 [kW]
Starting tractive effort	260/191 [kN]
Maximum speed	100 [km/h]
Weight	74 [t]

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[2] Siemens web-page.

[3] 1067 mm

The DM30AC of the GM Electromotive Division is used by Long Island Rail Road for hauling passenger trains, Figure 1.2. Drives and control are delivered by Siemens. It combines diesel operation with electric supply from a 650 V third rail. The diesel power is 2237 kW. The maximum speed is 110 km/h whereas the rated power when fed from the third rail is 2150 kW.

Figure 1.2 The GM-EMD DM30AC Dual System locomotive [Siemens web-pages]

Table 1.3 Ratings for the Dual-system locomotive DM 30AC

Year	1997-98
Diesel engine power	2237 [kW]
Continuous rating at 650 V dc	2150 [kW]
Starting tractive effort	360 [kN]
Maximum speed	110 [km/h]
Weight	128 [t]

1.2.2 Battery and diesel dual locomotives

A dual locomotive must not only be a combination of diesel motor and electric supply. In the US, Railpower has developed a Dual system locomotive with a diesel engine and batteries shown in Figure 1.3.

The locomotive is described as a Yard Switcher and the main purpose is to improve the environmental impact from by reducing the diesel engine operation. A comparison between a conventional Diesel-Electric locomotive and the Battery-Diesel Dual System locomotive is shown in Figure 1.4.

The locomotive is not a “classic” Dual System locomotive rather a hybrid locomotive as Figure 1.3 shows. That is the battery is used to allow the diesel engine to operate optimally from efficiency and emission point of view thereby reducing fuel consumption and emissions significantly. The operation is similar to the one used in hybrid road vehicles to reduce fuel consumption and thus CO_2 emissions.

Figure 1.3 The Green Goat a battery and diesel engine Dual System locomotive

As described briefly in 3.5 a significantly higher battery capacity would be required than what is used in the Railpower locomotive.

Table 1.4 shows that the maximum speed is relatively low since yard switching does not require high speeds. The manufacturer claims that the fuel consumption can be reduced by 30-45 % (and consequently the CO_2 emissions) whereas NO_x emissions are reduced by 80-90 %.

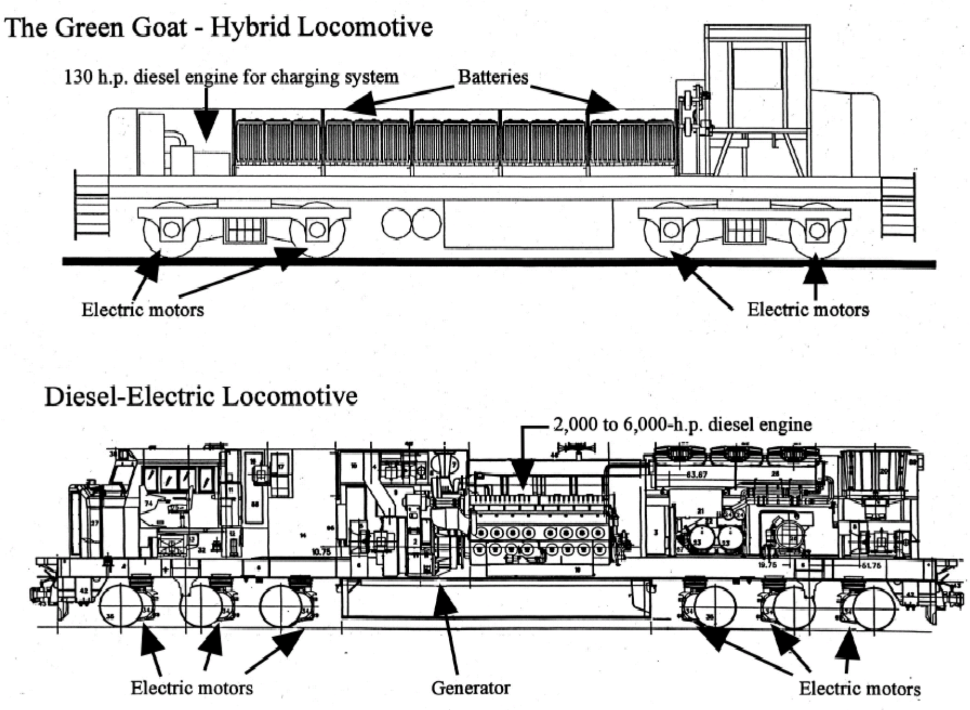

Figure 1.4 Comparison between a Diesel-Electric locomotive and the Battery-Diesel Dual System locomotive

Table 1.4 Ratings for the Battery-Diesel engine Dual-System locomotive of Railpower

Year	2003
Continuous rating diesel engine mode	[kW] 2000 hp
Starting tractive effort	[kN] 87.000 pounds
Maximum speed	32 [km/h]
Weight	280.000 pounds
Battery voltage and capacity	600 V/1200 Ah

1.3 Ratings of typical electrical freight locomotives

The German series 120.1 shown in Figure 1.5a) is a universal locomotive capable of both heavy freight operation and passenger services at high speed.

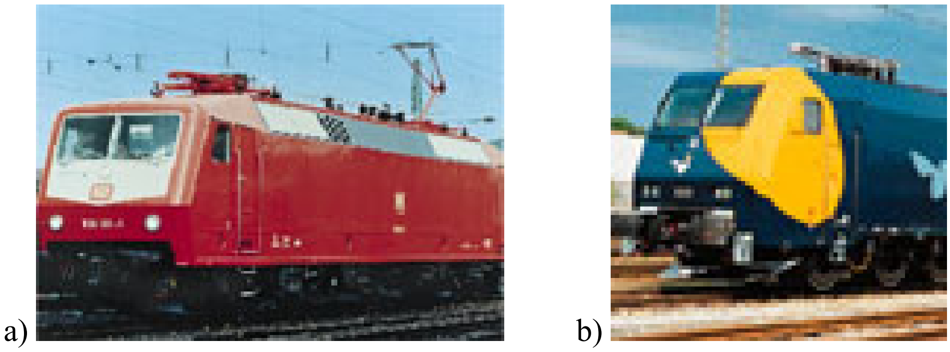

Figure 1.5 a) The German series 120.1 b) EG3100 Two-system locomotive for operation between Sweden and Germany via Denmark.

The power is therefore relatively high, Table 1.5. The weight and the starting tractive effort is however roughly the same as for the Swedish RC locomotive. The prototype 120.0 was the first locomotive to be equipped with three-phase inverters and induction machines.

Table 1.5 Ratings of the German series 120.1 universal locomotive

Year	1987/88
Continuous rating	5600 kW
Starting tractive effort	290 kN
Maximum speed	200 km/h
Weight	84 t
Battery voltage and capacity	600 V/1200 Ah

The ratings for the six-axle locomotive EG 3100 are on the other hand typical for modern six-axle locomotives. EG3100 is designed for a trailing load of 2000 t in slopes up to 1.5%. Its ratings are presented in Table 1.6

Table 1.6 Ratings of the EG 3100 locomotive (Öresundsloket)

Continuous rating at wheel	6500 kW
Starting tractive effort	400 kN
Maximum speed	140 km/h
Weight	129 t

1.3.1 The Swedish Rc2/Rc4 locomotives

The Swedish universal locomotive series Rc, shown in Figure 1.6 has been the dominating locomotive for hauling freight trains in Sweden for at least 25-30 years. It is therefore of interest to compare its performance with other freight locomotives as well as with estimated performance of the proposed Dual-System locomotive. The locomotive has been used both for hauling passenger trains and freight trains. The maximum speed has been increased to 160 km/h for passenger operation by a change of the gear ratio whereas the locomotives used for freight operation[4] has the maximum speed 135 km/h (Rc2 and Rc4).

The tractive effort diagram for the Rc locomotive is shown in Figure 1.7. The figure also shows the running resistance for some typical trains.

Figure 1.6 The Swedish Rc4 locomotive

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[4] Except for high-speed mail trains that operate at 160 km/h maximum speed

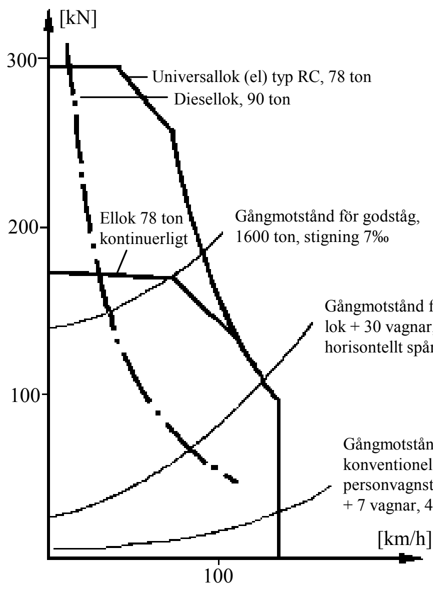

Figure 1.7 Tractive effort diagram for the Rc locomotive (freight version Rc2 and Rc4)

2 Tractive Effort and Power

When estimating the maximum trailing loads of freight locomotives it is generally assumed that an adhesion of 25% is possible to achieve. For an 80 t locomotive that would correspond to a starting tractive effort of approximately 200 kN. As was shown in 1.3 that is a typical value obtained for four-axle universal locomotives in freight operation. In Sweden the RC2 and RC4 locomotives to a great extent corresponds to those performance specifications.

In this study a maximum speed of 120 km/h is the initial assumption. If the locomotive is to be used also for high-speed freight a higher maximum speed would be required. For the sake of comparison the 120 km/h locomotive is compared to a locomotive for 160 km/h. It is assumed that the power is unchanged and that the speed increase is obtained by a change in gear ratio.

The axle load is generally limited to 22.5 t. That is, the total weight of a four-axle bogie locomotive is 90 t. As shown later that weight is not that critical for a Dual-System locomotive (2.1.4), at least when the power is relatively limited.

In the calculations a wheel diameter of 920 mm has been used.

2.1 Estimation of tractive effort

The different applications determine the required tractive effort and power for the Dual system locomotive and are possibly determined by the following factors:

- What are the required trailing loads and speeds for single- and multiple connected locomotives?
- Required trailing load and speed when operating outside the catenary system
- Required tractive effort when switching that is, operation at low speed

A fundamental idea with the study has been to explore the opportunity to use components and systems developed for use in EMU[5] or DMU trains. Traction motors for multiple unit trains are designed for a rated power of typically 500 kW and that level will therefore be used when the tractive effort is calculated.

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[5] Electric Multiple Unit and Diesel Multiple Unit

2.1.1 Comparison of traction motors and transmission for locomotives and EMUs.

There is a clear difference between traction motors for locomotives and for EMUs. A motor for an EMU is an industrial product manufactured in relatively larges series whereas motors for locomotives are manufactured more manually in small series.

The same relation is true for the transmission. Table 2.1 describes these differences and gives rough estimates of price and performance.

Table 2.1 Comparison between traction motors and transmission for locomotives and Multiple unit trains.

	Traction motor EMU 500 kW	Traction motor locomotive, 1000 kW
Rotor design/manufacturing	Industrial manufacturing e. g. with cast aluminium rotor.	Rotor bars. Can be made of copper.
Maximum rotational speed	>5000 rpm	3-4000 rpm
Mass	Approx. 1000 kg	>2000 kg
Relative cost for the motor	<200 kSEK	Approx. 3 times the EMU motor, that is ca 600 kSEK
Relative cost for transmission[6]	Approx. 150 kSEK	Ca 3-400 kSEK

The table shows that the relative cost for an EMU motor including transmission of 500 kW is 1/3 of that for a 1000 kW locomotive motor. Evidently it is possible to obtain substantial savings in cost for traction motor and transmission if EMU motors for a lower power could be utilized. However, it is necessary to estimate the obtainable tractive effort of such a locomotive to find out if it is sufficient for the assumed operation.

2.1.2 Torque of the traction motor

A base speed of 2000 rpm and a maximum speed of 5000 rpm are assumed. Evidently the base and maximum speed can be chosen differently. At the end of this Section some aspects on the choice of speed are given. The rated torque is

$$T_N = \frac{P_N}{\omega_{bas}} = \frac{500k}{2\pi \frac{2000}{60}} = 2.387 \text{ kNm}$$

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[6] The compared transmission consist of a bogie suspended motor and unsprung gearbox. There are other feasible solutions that might be more cost effective in this application.

The maximum torque is in the range of 2.5 times the rated torque, that is 5.968 kNm.

For a loco with four traction motors the total rated and maximum torque are

$$T_{4N} = 9.549 \text{ kNm}$$

$$T_{4\max} = 23.873 \text{ kNm}$$

2.1.3 Gear ratio

A speed of 120 km/h corresponds to 33.3 m/s. The circumference of the wheel is πD=2.89 m. The maximum wheel speed thus is

$$\frac{33.3}{2.89} \times 60 = 692 \text{ rpm at } 120 \text{ km/h}$$

For a maximum speed of 160 km/h the rotational speed is 923 rpm.

The gear ratio then becomes

$$k_{120} = 5000/692 = 7.225 \text{ at } 120 \text{ km/h}$$

$$k_{160} = 5000/923 = 5.417 \text{ at } 160 \text{ km/h}$$

2.1.4 Tractive effort

The tractive effort of the locos is calculated from the torque of the traction motors and the calculated gear ratios. The total torque acting on the wheels is

$$T_{wheel} = 4kT_N \,.$$

The tractive effort is then obtained as

$$F = \frac{T_{wheel}}{r_w}$$

where r_w is the wheel radius.

The quotient between base speed and maximum speed of the traction motors determines the base velocities. If the maximum velocities are 120 km/h 160 km/h respectively, the base velocities become ${}^{2000}\!/_{5000} \times v_{\max}$ that is 48 km/h and 64 km/h. Figure 2.1 shows the calculated continuous tractive efforts for the two locomotives.

Assuming an adhesion of 0.25 and that the locomotive for 120 km/h and 160 km/h has a mass of 90 t and 80 t respectively. The tractive effort limited by the adhesion would then be

$$F_{120/90} = 90 \times 0.25 \times 9.81 = 220 \text{ kN}$$

$$F_{160/80} = 80 \times 0.25 \times 9.81 = 196 \text{ kN}$$

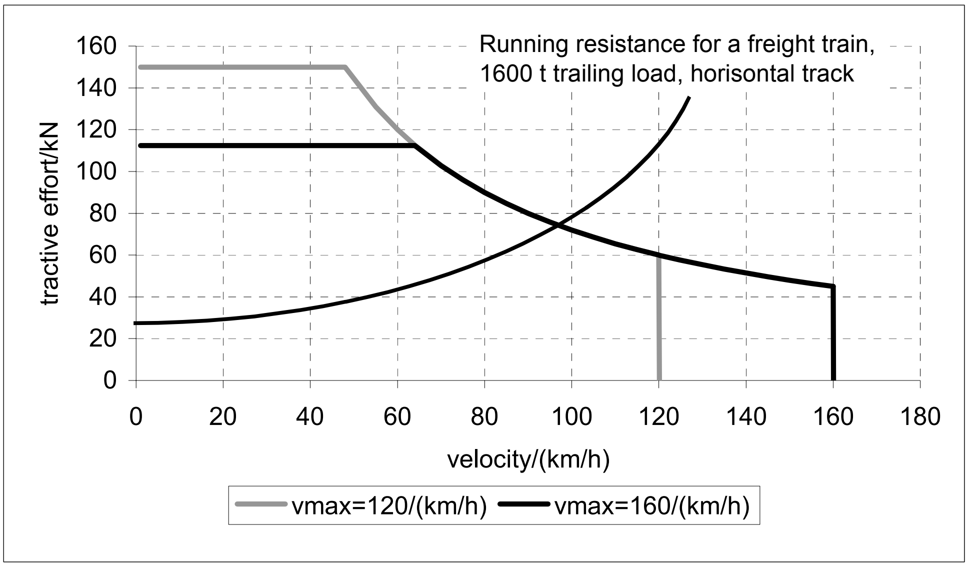

Figure 2.1 Tractive effort diagram for continuous operation at 120 km/h and 160 km/h (electrical supply)

that is, the adhesion will be very low for a locomotive with the tractive effort curve in Figure 2.1. For a locomotive with a maximum velocity of 120 km/h and a mass of 90 t the starting tractive effort can be reached at a approximately 17-18 % adhesion implying that for the same adhesion (0.25) as for a normal universal freight locomotive the mass of the Dual system locomotive could be substantially reduced. However, keeping a relatively high mass would mean that the tractive efforts as indicated by the diagram in Figure 2.1 are reached at relative low values of the adhesion (less friction).

Figure 2.1 also shows an estimation of the running resistance of a freight train on horizontal track when the trailing load is 1600 t. Compared with the RC locomotive described in 1.3.1 the balanced speed is lower due to the fact that the estimated Dual system locomotive has lower power than the RC locomotive. Observe that the RC locomotive is operating in field weakening mode above 70 km/h thus having a power lower than the rated one 3600 kW.

At diesel operation the power is limited to roughly 1000 kW that is, roughly half the power is available at electric supply hence, the tractive effort at rated power will be half the one for electric supply in Figure 2.1. However the starting tractive effort is the same since the converters still can produce the same current and thus the same torque of the motors.

2.1.5 The influence of traction power on possible trailing loads

Green Cargo AB claims that the Rc4 locomotive is able to haul trains with a total weight of 1600 metric tones[7]. The trailing load for a RC2 is somewhat lower, 1400 t.

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[7] Private communication

The maximum speed then is 100 km/h. According to Figure 1.7 the continuous tractive effort for the Rc4 is approximately 130 kN and the maximum tractive effort is roughly 170 kN. The continuous tractive effort of the Rc locomotive at 100 km/h is almost twice the one of the Dual system locomotive due to a much higher power rating of the Rc locomotive.

The weight of an Rc locomotive is 78 t. If only the adhesion weight is considered a direct scaling in proportion to the desired trailing load gives to hand that[8]

- A trailing load of 2000 t requires an adhesion weight of 98 t, that is an axle load of 24.5 t.
- A trailing load of 1900 t requires an adhesion weight of 92 t, that is an axle load of 23 t.

An important issue for further studies then is to find out the permissible maximum speed at those axle loads.

In a simple comparison the required power for a trailing load of 2000 t was estimated[9] By scaling of the Rc locomotive ratings the power level is estimated to 4.5 MW.

The heavy terminal locomotive T44 has a rated power of 1.2 MW and its maximum trailing load in main line service is 900 t. The V11 terminal locomotive has a maximum power of 900 kW corresponding to 75% of the T44 power rating. These values motivate an assumption that the required power rating at diesel operation should be in the range of 1000 kW.

The tractive effort diagram in Figure 2.1 shows that the limited power might be a drawback at electric railway traction. To increase the trailing load at higher speeds relatively high power is required. It is then likely that multiple-operation will be necessary. At diesel operation a lower maximum speed can be sufficient.

These very simple comparisons show that it is interesting to compare a 2 MW Dual System locomotive with a Dual System locomotive for 4 MW. The higher power is advantageous at electric operation whereas the higher torque of the motors improves the trailing load at diesel operation. A drawback is of course that it is then not possible to use only components for EMUs or Intercity trains.

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[8] Bark, P., *Effektiva tågsystem Delrapport III, Effektiva tågsystem för vagnslast- och systemtåg-utvecklinsmöjligheter och alternativa koncept*, Stockholm June 2003

[9] Bark, P., *Effektiva tågsystem Delrapport III, Effektiva tågsystem för vagnslast- och systemtåg-utvecklinsmöjligheter och alternativa koncept*, Stockholm June 2003

3 Principle design of the locomotive

It is proposed that the locomotive should be utilizing a modular design with a central cab according to Figure 3.1. The diesel power module should be based on existing diesel engines for heavy trucks or industrial diesel engines. The power for such engines is typically in the range of 500 kW. Besides the diesel engine the module includes generator, fuel tank and control equipment. As a consequence the diesel power will be a multiple of 500 kW. Other solutions including a rail diesel motor in the MW range is of course also possible[10].

These power modules should become reasonably compact and it is possible that the locomotives could be equipped with up to four units corresponding to a power of 2 MW. However, it is more likely that two diesel engine units with a total power of 1 MW is the economically most attractive solution.

The converters are preferably mounted under the drivers cab as shown in the figure. To increase the number of converters produced, thus lowering the item price, the converters should be similar to those used in modern Electric Multiple Unit trains. An alternative location is between the driver's cab and the diesel engine units. There are several aspects that have to be considered when it comes to a more detailed design of the locomotive, not at least electromagnetic interferences from the converters.

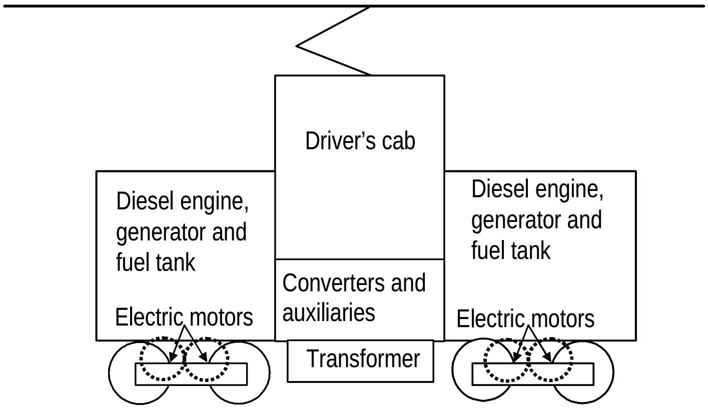

Figure 3.1 Principle design of a modular Dual system locomotive

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[10] Studied in the ongoing TFK, KTH project

The traction transformer is mounted under the frame between the bogies as shown in the figure. The traction motors are mounted in the bogies. That is today the normal solution.

3.1 Main locomotive concepts

The main objective has been to study the possibility to design a new kind of Dual-System freight locomotive based on EMU components that are able to improve the performance of future rail freight operation. From technical point of view it is the electrical propulsion system that contributes most to the performance of the locomotive regarding tractive effort, power and maximum speed. Especially important is the choice of traction motors. Four possible configurations according to Figure 3.2 have been considered. The different configurations have traction motors of either 500 kW (EMU) or 1000 kW (typical locomotive motor). If the locomotive is equipped with four traction motors of 1000 kW according to the concept at the top of the figure the total power is substantially higher than for the RC locomotive.

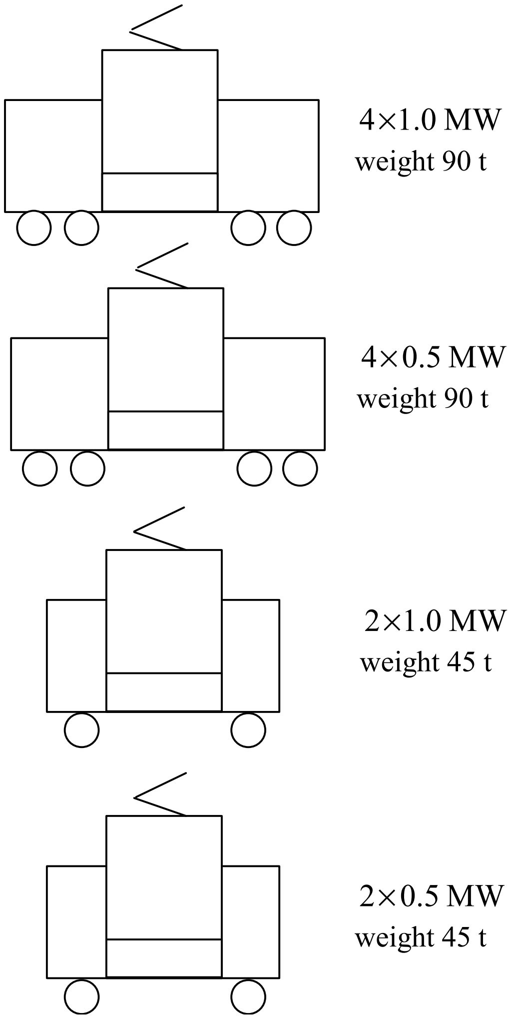

Figure 3.2 Different locomotive concepts and choice of traction motor. The specified weight is the maximum weight at 22.5 t axle load.

The cost for such a solution can be substantially higher and an alternative with a traction motor size typical for multiple unit trains is an attractive solution. The initial ambition is to be able to use equipment that is manufactured in relatively large series for other vehicles. Traction motors with a rated power of 500 kW is about the largest power used in multiple unit trains.

3.2 Diesel engine and generator

The cost of a diesel engine with a power of 500 kW is about £30.000[11] that is approx. 400.000 SEK. Generator and cooling equipment etc. are assumed to have a higher price. A reasonable assumption therefore is a price of 1 MSEK per 500 kW diesel power. The basic idea will be to use an industrial diesel engine to lower the cost.

3.3 Electric system

Figure 3.3 shows the conceptual design of the propulsion system for two traction motors, typically one bogie. The power generated by the diesel engines and the generators has to be rectified before it is fed to the inverters and the traction motors. The most attractive solution is then to use the same line side rectifiers that are used when the system is fed from the electric supply. A less attractive alternative would be to use a separate rectifier (could be relatively simple) as indicated with dashed lines.

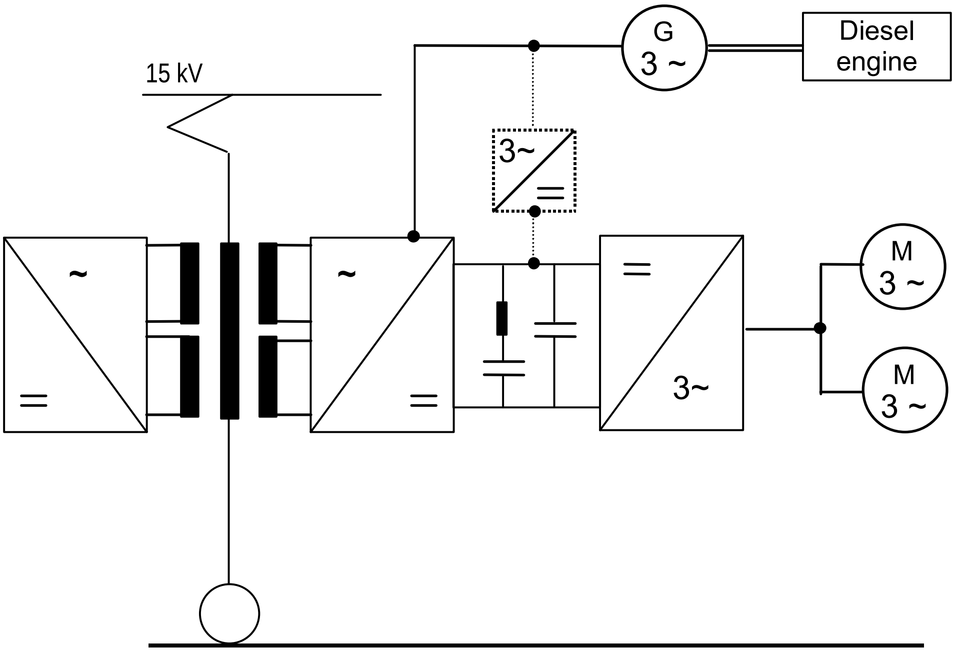

Figure 3.3 Propulsion system for one bogie (two traction motors).

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[11] Information from Cummins obtained during Nordic Rail 2001.

A very rough estimation of a possible price for the propulsion system and related devices has been done. The maximum power for the specified equipment is 2950 kVA that is reasonable in conjunction with the other assumptions. ”The market price” without taking possible business considerations into account is in the range from 6-8 MSEK[12].

3.3.1 Transformer

The traction transformer is a heavy and bulky device. A 3 MVA transformer has a weight of roughly 6-7 t. The weight itself is not a problem for freight locomotives but special attention has to be paid to the space requirements in the Dual Locomotive application.

3.3.2 Converters

A typical rating of modern converters for Regional trains is 1500-1600 kVA and a maximum power of 1700-1800 kVA. The possibility to feed two traction motors per converter is depending on the current handling capacity of the converter. It is today not possible due to current limitations. However, for a future Dual mode locomotive it is reasonable to assume that it will be possible.

If it is assumed that two modules powers four traction motors. Further two modules can be used as line side converters. The power and current handling capacity of this configuration has to be analysed more in detail. The potential improvement regarding power and current of future converters has to be considered. The total weight of such a four-module set is 1-1.5 t.

3.3.3 Control system (TCC) and ATC

The cost of the control system and ATC for an IC train is generally in the range of 10-15 % of the total cost for the propulsion. For freight locomotives that figure should be substantially lower.

3.4 Other equipment

3.4.1 Frame and push and pull equipment

The cost of frame and push and pull equipment are relatively moderate. A 12 m frame is estimated at 100 kSEK. The weight is approximately 7000 kg. Push and pull equipment is roughly 50 kSEK.

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[12] Covered in the ongoing TFK/KTH project

3.4.2 Bogies (2 or 4 axles per loco), air pressure and braking

The basic assumption is that the price of a two-axle bogie is approximately 300 kSEK. It can possible to lower the cost if a simplified design based on bogies for freight cars can be used. For such a case the cost can be as low as 150 kSEK per bogie. The maximum speed then is limited to 120 km/h.

A bogie for 160 km/h is much more expensive. A rough estimation is 600 – 700 kSEK per bogie including braking devices such as disc brakes etc.

3.4.3 Driver's cabin

Kockums has developed a relatively simple cabin intended for a working vehicle[13]. The price is approximately 500 kSEK. To be able to fit in a locomotive application a more robust design is required to among other thing be able to carry a pantograph. A *wild* estimation of the cost is 1 MSEK. An important issue is whether a single cabin solution is possible or if two cabins are necessary. Due to the substantial cost of the cabin it is assumed a single cabin solution is feasible.

3.5 Dual system locomotives with batteries and electric supply

In 1.2.2 a Dual-system or Hybrid locomotive with diesel engine and batteries was described. Another possibility is a Dual-system locomotive with electrical supply and batteries.

The performance in battery operation limits the operation to yard switching during a limited time. There are two possible designs. The locomotive can either be operated as a hybrid vehicle where the battery is used to lower fuel consumption and emissions, as was shown in 1.2.2 or it can be used as a Dual system vehicle. The latter means that the locomotive either uses the diesel engine or the battery supply. Combinations are also possible.

Assume that the train in average consume a power of 500 kW during one hour. The energy then is 500 kWh. If the battery voltage is 120 V that energy corresponds to 4167 Ah.

A truck battery for 5-600 Ah has a cost of approximately 75-80 kSEK. The cost for 4000 Ah then should be in the range of 600-650 kSEK. The lifetime is limited to a few years.

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[13] Presented at Nordic Rail 2001

4 Conclusions and future work

The initial estimations of performance and cost are of course not enough to be able to draw precise conclusions regarding the design and cost of the locomotive. More detailed analysis of running times for different trailing weights and locomotive ratings have to be made as well as examinations of possible configurations of the propulsion system as well as the mechanical lay-out. However, the initial calculations indicate that a power level of at least two MW is feasible as long as sufficient starting tractive effort can be obtained.

Dual System locomotive has many potential advantages in a future freight transportation system and since the initial results obtained in this report shows possible solutions for such a locomotive a project focusing on the Dual System locomotive has been initiated by TFK and KTH. That project will be able to compare and evaluate different ratings etc. Results from that project are expected during the autumn of 2005.