EC-7

ELECTRICITY COMMISSION

MEMORANDUM on TECHNICAL DATA

NOTE : There is circulated for information as an attachment to this Memorandum an excerpt from the Wartsila Technical Journal, number 2 of 2014 (pages 21-23) on various technical data relative to electricity, namely **Availability and Reliability, Capacity, Heat Rate / Electrical Efficiency, O + M and Consumables** and certain **Other Parameters** : and from page 35 of that Journal various technical **Definitions.**

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Max capacity factor

The capacity factor is the ratio between the actual energy output (including derating, planned and forced outages) of a plant vs. its nominal ISO rated capacity, over a given period of time. By deducting maintenance and forced outages, we have the **availability**. When further deducting the power lost due to ambient condition derating, we finally have the **max capacity factor.**

$$Capacity\ Factor = \frac{(A\ (MWh))}{(Y(MWh))} = \frac{(Y\text{-}I\text{-}D\text{-}B)}{Y} = \frac{(PH_h\text{-}POH_h\text{-}MOH_h\text{-}FOH_h) \times Actual\ capacity)}{(PH_h \times Nominal\ ISO\ capacity)} \leq 1$$

Where:
The "max capacity factor" assumes that C (Reserve Shut Down) and J (Plant Usage) = 0, i.e. the plant would always be needed and never in reserve shutdown. It is the highest capacity factor that can be achieved in theory.

- A = Total amount of energy produced
- Y = gross maximum generation at nominal ISO conditions
- SH_e = Total amount of energy produced
- PH_e x *Nom ISO cap.* = Total available energy that would have been produced at nominal ISO output running 8760h/year

Heat rate / electrical efficiency

Electrical efficiency at 20°C and sea level (average ISO conditions)

This indicates the plant's total net electrical efficiency based on a lower heating value (LHV) at 20°C and at sea level (*average ISO conditions*) given at various loads. A plant with several units can turn down some units and run the remaining ones at full load, thereby eliminating part load efficiency losses. This type of operation is called the *efficiency mode.*

Temperature derating efficiency loss 20/35°C

Most technologies have a lower efficiency at a higher ambient air temperature. Therefore, the efficiency given at average ISO conditions needs to be multiplied by the **temp. derating efficiency loss 20/35°C** to find the actual efficiency at a location where the temperature is 35°C. The efficiency loss is defined in the same way as for the power loss explained in Figure 2.

Altitude derating efficiency loss 0/1500 m.a.s.l. (meters above sea level)

Just as technologies have a derated output at higher ambient temperatures, so too do they have a derated output at higher elevations where the air is thinner (i.e. lower density). Therefore, the efficiency given at average ISO conditions needs to be multiplied by the **altitude derating efficiency loss 0/1500 m.a.s.l.** to find the actual efficiency at a location 1500 metres above sea level.

Efficiency degradation

Some technologies will suffer a reduction in efficiency after a certain operating time. This factor measures the average efficiency reduction over a four year/0-32,000 hour period. After a major overhaul, with the critical combustion parts having been replaced, typically most of the lost efficiency is recovered. When performing long-term portfolio modelling, it is crucial to take these losses into consideration when considering fuel usage. The efficiency loss is defined in the same way as for the power loss explained in Figure 3.

Pulse efficiency – 1 hour load cycle

Many plants are required to perform several starts and stops per week, or even per day. The full load efficiency has, therefore, very little relevance in these situations. In this case, the average efficiency during a one hour running cycle, here called **pulse efficiency – 1 hour load cycle,** might be a better number to use in simulating power plants that are meant to start and stop frequently (Figure 5). This efficiency number also needs to be multiplied by the temperature and altitude de-rating factors, as well as the ageing factor.

O&M and consumables

Lubricating oil consumption

This parameter quantifies the typical lubricating oil consumption. Certain technologies do not consume oil in a continuous way during normal operations, but still require oil changes at regular intervals.

Water consumption

The amount of water that each technology typically consumes (i.e. discards) is mainly dependent upon the type of cooling system. Closed-circuit and air-cooled systems can consume very little, while cooling tower solutions consume a considerable amount of water. Both values will be available for those technologies in which both systems are typically used.

Variable O&M cost

Variable O&M costs are those costs that are incurred only when the plant is running. The given figure is calculated as an average of a 10-year or 64,000-hour time period, on a €/kWh basis including:

- All spare parts for the complete plant (prime movers and auxiliaries) according to standard maintenance schedules
- Maintenance labour

But excluding:

- Import duty and inland transportation of spares
- Consumables like water, chemicals and lube oil
- Possible unscheduled maintenance for the prime mover and auxiliary equipment
- Oil , water & fuel oil analyses
- Safety spares and swing sets

Fixed O&M cost

O&M costs are incurred regardless of whether the plant is running or not. They are calculated in terms of €/kW per year, and are based on the average plant size

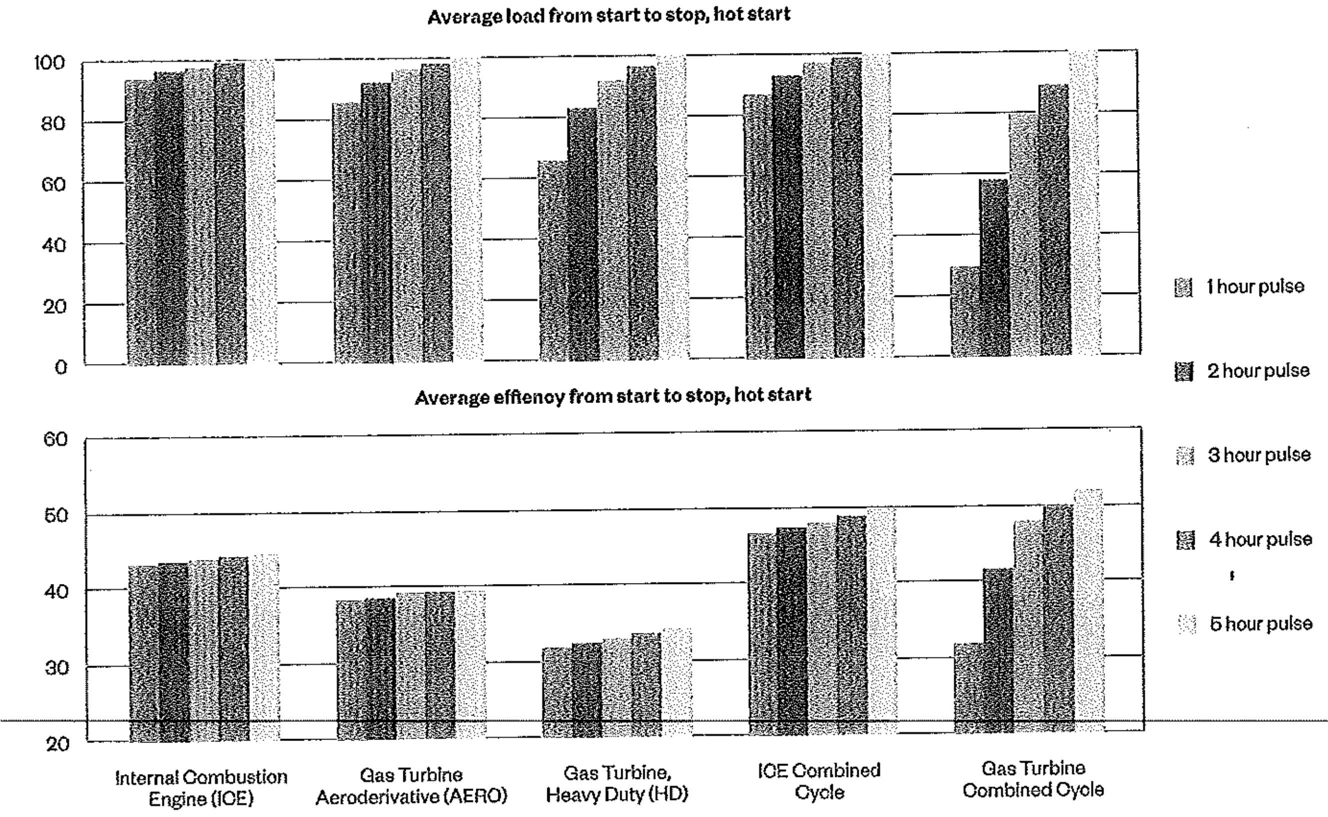

Fig. 5 - Pulse efficiency vs. full load efficiency for various technologies.

mentioned in the table. They include:

- Operating personnel
- Operation planning, spare part coordination, plant safety
- Contracted service fees (if any)
- Office equipment and basic personnel training
- Daily/weekly routine checks and minor services
- Buildings (power house & workshop/warehouse) maintenance & cleaning

But excluding:

- Liability Insurance
- Internet, phone costs
- Vehicle costs, protective gears, tools
- Advanced personnel training
- Environmental monitoring and waste handling services
- Taxation services and audits

Start-up costs (€/MW/start)

Every time a power plant is fired up there will be fuel burned so as to start-up, synchronize, and make the plant ready to produce electricity. The longer this period the higher the start-up fuel costs are. Furthermore, some technologies incur increased wear and tear every time they are started. This is due to the mechanical and thermal stress from transient conditions. Usually, the quicker the start–up and increase in temperature, the greater the stress and wear on the equipment. This results in a reduced lifetime of the components. Gas turbines are particularly sensitive to this, and they use a term called EOH (Equivalent Operating Hours) which is used to convert each start to an extra amount of normal running hours. The **start-up cost** in The Table of Power Generation includes the approximate cost of replacing components earlier, plus the additional fuel burned during a start-up.

Other parameters

Typical plant construction time

This represents the amount of time it typically takes to build the power plant from the issuing of construction permits and the EPC contractor having access to the site.

Plant lifetime

This means the number of years the resource is expected to be 'used and useful', based on various factors such as OEM guarantees, fuel availability, and environmental regulations.

Technology cost change

This gives an estimate of how the cost of the technology has evolved during recent years, and a forecast of what the annual cost change will be in the upcoming years.

Utility portfolio optimization with Smart Power Generation

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Portfolio optimization is a key to sustainable, affordable and reliable power systems. This has never been more relevant than it is for utility systems tasked with meeting aggressive renewable targets through a renewable portfolio standard (RPS) or by other means.

Background and motivation

Portfolio optimization is the key to integrating renewable energy. Wärtsilä has shown with great success exactly how and why it is a key player in the optimization process. We began by performing annual dispatch studies of power systems with aggressive renewable penetration to understand how flexible, modern, state-of-the-art, modular gas-fired internal combustion engines (ICEs) can improve system performance.

One study system was the California Independent System Operator (CAISO), which delivers electricity to 80% of the state of California (CA) and handles 35% of the electricity load in the western United States. California has a legislated renewable portfolio standard (RPS) requiring 33% of load be served by renewable energy,

Definitions

Frequency restoration process The process of activating reserves to restore system frequency to nominal frequency.

Integral quality indicator The absolute value of the frequency deviation from 50 Hz divided by the difference between the respective trumpet curve and 50 Hz.

Merit order activation Available reserves are activated consecutively, based on their price in the merit-order list (cheapest being activated first), up to the amount of the imbalance.

Net load The total electricity demand minus renewable generation. This remaining part of the demand has to be met with power generation that can be dispatched, i.e. generating units that can be ramped and/or started and stopped as needed.

Non-spinning reserve Off-line capacity available to come on line in the event of a contingency; must satisfy requirements for start-up time and ramping capability.

Open loop imbalance is composed out of the different types of imbalances: forecast errors, block trade effects and disturbances and as such the required Frequency restoration reserve capacity depends on these phenomena.

PLEXOS model in this study, the PLEXOS model is calculated by co-optimising the generation of electricity and FRR requirements, taking power plant constraints (such as ramp rates and starting time) into account, resulting in the least-cost solution for generating electricity while having sufficient reserve capacity available. Costs due to activation of reserves were not assessed in this part of the study.

Pro rata reserve activation All available reserves are activated proportionally (to their respective amount of capacity available for balancing) up to the amount of the imbalance.

Spinning reserve Online contingency reserve; synchronized to the grid.

Open loop imbalance is composed out of the different types of imbalances: forecast errors, block trade effects and disturbances and as such the required Frequency restoration reserve capacity depends on these phenomena.

The President of PennWell Corporation, Robert F. Biolchini, handing the Best Paper Award to Market Development Director Melle Kruisdijk of Wärtsilä.

The Wärtsilä NO_x Reducer for IMO Tier III compliance

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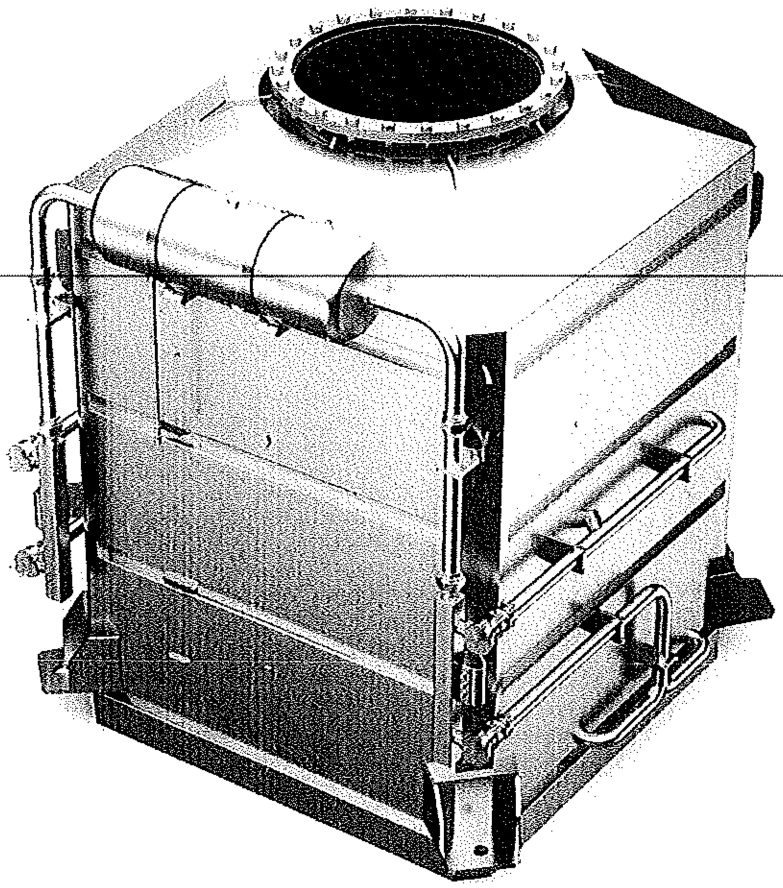

The Wärtsilä NO_x Reducer represents the latest in emission abatement technology. It offers ship owners a welcome opportunity to optimize operations and meet the growing demand for environmentally sound traffic.

Today, new and more stringent legislation concerning nitrogen oxide (NO_x) emissions is a global phenomenon, and governing bodies like the International Maritime Organization (IMO) are introducing stricter regulations. The Wärtsilä NO_x Reducer (NOR) system is an exhaust gas after treatment device, based on Selective Catalytic Reduction (SCR) technology. It lowers the exhaust levels of NO_x and meets the upcoming NO_x requirements.

The IMO NO_x emission standards

The first IMO Tier I NO_x emissions standard entered into force in 2005. It applies to marine diesel engines installed in ships constructed on or after January 1, 2000 and prior to January 1, 2011.