

PAPER NO. 3.2.

SOFT START TECHNIQUE FOR DIESEL GENERATOR SETS

Lars Fredlund
Deputy manager operations unit 4
Swedish State Power Board
Ringhals Nuclear Power Plant
Väröbacka, Sweden.

A diesel motor in a nuclear power plant should be of a well-proven design. It is designed for long periods of troublefree duty, but not for the frequent and rapid test starts called for by the technical specifications. In order to decrease the dynamic forces and thermal stresses, a soft-start scheme has been implemented. By limiting the fuel injection the diesel generator will reach full speed in appr 30 seconds. The fuel limiter is a pneumatic cylinder which mechanically limits the travel of the terminal shaft of the governor.

1. Electrical layout

Ringhals Nuclear Power Plant has 4 units, 1 BWR (750 MW) and 3 PWR (800 MW, 915 MW and 915 MW). Each unit has two turbines.

The plant internal electrical system is divided into two main divisions, each divided into two subdivisions. Thus each unit has four trains. The AC power distributions is at 6,6 kV and 0,5 kV. The 6,6 kV system is divided in two parts, ordinary net and diesel net, with two interconnecting breakers in series. Both breakers open on the black-out signal from the diesel sequencing equipment. Each 6,6 kV net has parallel transformers to 0,5 kV, also divided into ordinary net and diesel net.

The diesel generators are connected to the 6,6 kV diesel net, one for each of the four subdivisions. As the connected loads are the same for each pair of diesels (E.g. DG310 and DG320 in figure 1) there is an interconnecting tie which could be used for handling crosswise faults during loss of offsite power.

Also the DC and inverter fed AC systems are four trains, with the exception of some systems which only feed the turbine auxiliaries.

2. Diesel generator data

	R1, R2	R3, R4
Manufacturer	SACM, France	NOHAB, Sweden
Speed	1500 rpm	1000 rpm
Diesel motor output	2944 kW	2650 kW
Overload capacity 1 h each 24 h		3018 kW
Diesel generator power	3450 kVA	3450 kVA
Power factor	0,8	0,8
Unit voltage	6,9 kV	6,9 kV

The diesels are water-cooled and with air starting system. They have no shared auxiliary equipment. Supervision from the central control room is by sum of alarm for each diesel, one for tripping faults and one for non-tripping faults.

3. Reason for soft-start

The technical specifications for a nuclear power plant calls for regular tests to demonstrate the capability of the diesel sets to start, maintain speed and voltage and verify loaded conditions.

These tests are normally carried out by performing a simulated automatic start. The DG set will reach no-load speed in 6-8 seconds.

A diesel motor in a nuclear power plant should be of a well-proven design, which means that the original motor is normally a stationary or marine diesel. The motor is designed for long periods of troublefree duty, but is not intended for frequent starting in the manner set out in the technical specifications. The rapid starts cause large dynamic forces and thermal stresses, which in the long run will cause damage. [1]

During the commissioning period of Ringhals unit 3 and 4 it was found that the diesel motor cylinders were scratched because the oil film dried out between two test starts (once every two weeks). A number of contributing factors were recognized. A simple and straight forward solution to the problem was introduced. The test interval was shortened to once every week, and thus the oil film could be renewed before drying out. It should be noted that the problem was not a safety issue, but a question of testing procedures and guarantee.

However this frequent starting could be a contributing factor towards a higher unavailability. Some method of limiting the acceleration should decrease the stresses, and lessen the risk for failure of the diesel motor due to too many starting attempts.

By increasing the starting time the acceleration would decrease. This could be achieved by limiting the fuel injection during start-up of the diesel motor. At the same time the method must not in any way interfere with emergency starts. Thus the soft-start technique was developed and implemented.

4. Soft-start equipment

The fuel limiter is a pneumatic cylinder with spring return which mechanically limits the travel of the terminal shaft of the governor. The travel of the cylinder is adjusted so that maximum starting time (25-30 seconds) is achieved and still there is a suitable margin to the point where the diesel will not start and accelerate (figur 2).

Spurious fuel limiting is prevented in two ways.

The diesel sets have three modes of operation: auto, hand and test. Normal stand-by mode is auto. The soft start equipment can only be energized in the test mode, and only for a preset period of time, 10-15 seconds longer than soft-start starting time. The air supply valve has three ports and vents the soft start cylinder to the air when not energized.

The air supply to the soft start equipment is manually closed when not in use and the soft start cylinder vented to the air. (Figure 3).

Also the position of the soft start cylinder is supervised by a limit switch.

5. Periodic testing

The technical specifications for all Ringhals units specify the same periodic testing requirements.

- Starting once every two weeks
- Load running for 1 hour every month

All these tests are soft-started. Only once every third month, before a load test, the diesel is started without fuel limiting.

In addition to the requirements, the R3 and R4 diesels are soft-started every week in order to lessen the risk for cylinder scratches.

During a soft start the same components and auxiliaries are tested as during a rapid start. The only parts not thoroughly tested are the governor and the overspeed equipment because the limited acceleration gives a very slight speed overshoot. However, a fault in the governor would certainly be noticed by oscillating operation speed. The probable failure modes of the overspeed equipment are not very dependant on the speed overshoot and it should also be noted that on a real demand the base load is connected before nominal speed is reached and thus decreases the overshoot.

6. The mobile diesel generator set

In order to even more improve the reliability of the onsite power sources, Ringhals has bought a mobile diesel generator set. This can replace any of the 16 stationary diesels.

The diesel motor is the same as in units 3 and 4, but the motor is air-cooled. Directly connected to the motor is a hydraulic pump feeding the ventilating fans.

The mobile set is docked outside the diesel generator which should be replaced. Through a hatch the 6,6 kV cables are connected together with 0,5 kV, control and supervision and also a fuel hose. Mounted on the vehicle is only a 3 cubic meters fuel tank which means that the set is intended for using the stationary diesel fuel day tank.

As all the auxiliaries are on the vehicle, even the batteries for control and power, the diesel set is only depending on a 0,5 kV feeder and a fuel connection from the unit. (Figure 4)

After operating two isolators, opening the fuel valves and putting a switch in the local diesel control room in position "mobile", the mobile diesel generator set has completely replaced the stationary one. As the mobile set behaves exactly the same as the ordinary stationary set, diesel sequencing equipment and other control systems are not affected.

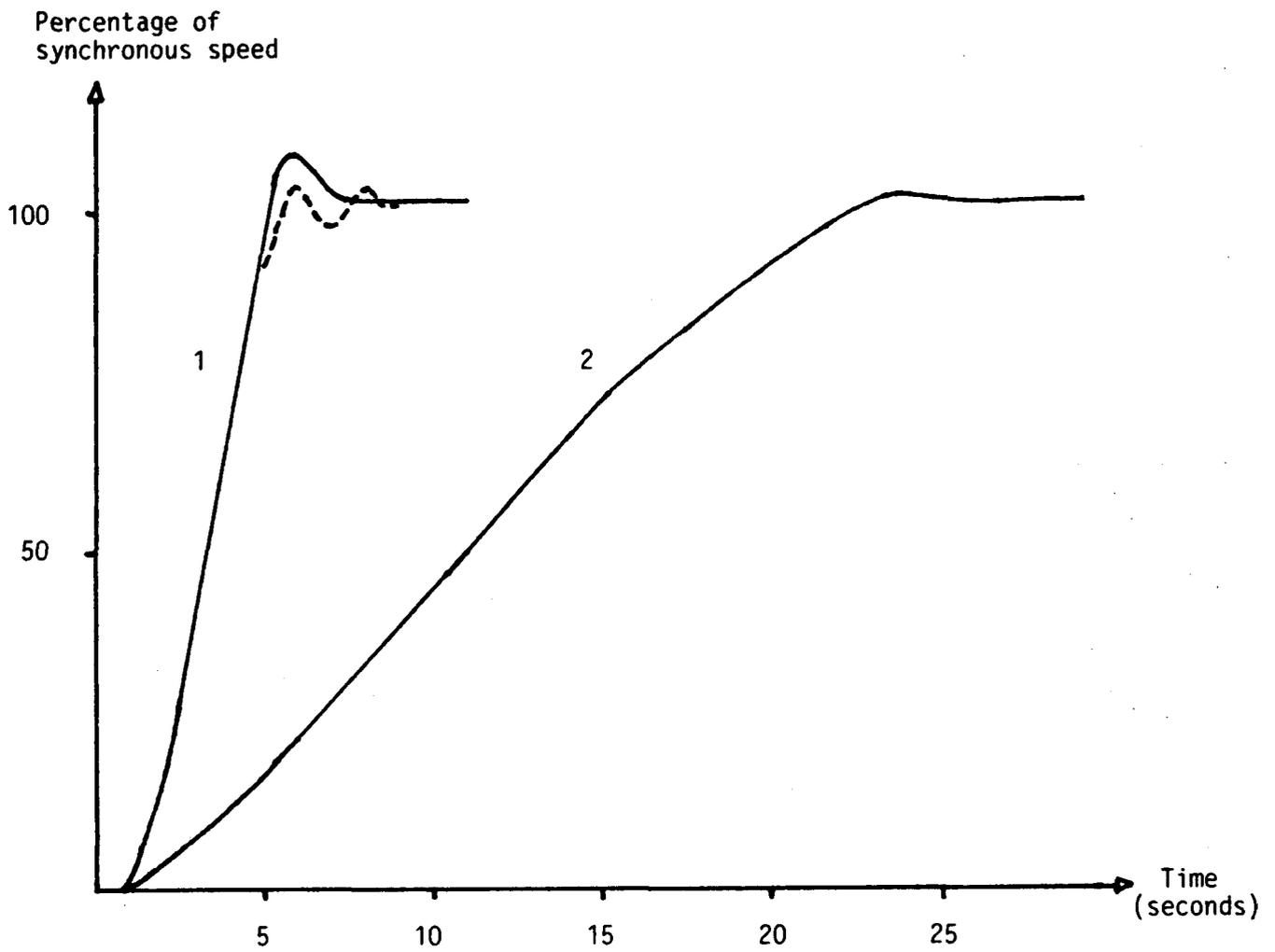
The technical specifications calls for cold shutdown if one out of four diesel generators of a unit is not operable for more than 48 hours. The mobile set is intended for minimizing the risk of this forced shutdown.

As the vehicle is selfpowered, the estimated time for docking, connecting and testing before declared operational is 4-12 hours.

The potentially best and most probable use of the mobile set is for replacing the stationary set during maintenance. Thus the diesel overhaul can be carried out outside refuelling outage.

References

- [1] NRC Questions Diesel Testing
Nuclear Industry October 1984 p 16-24



1. Rapid start. Dashed with connection of base load.
2. Soft start.

Figure 2. Typical acceleration curves.

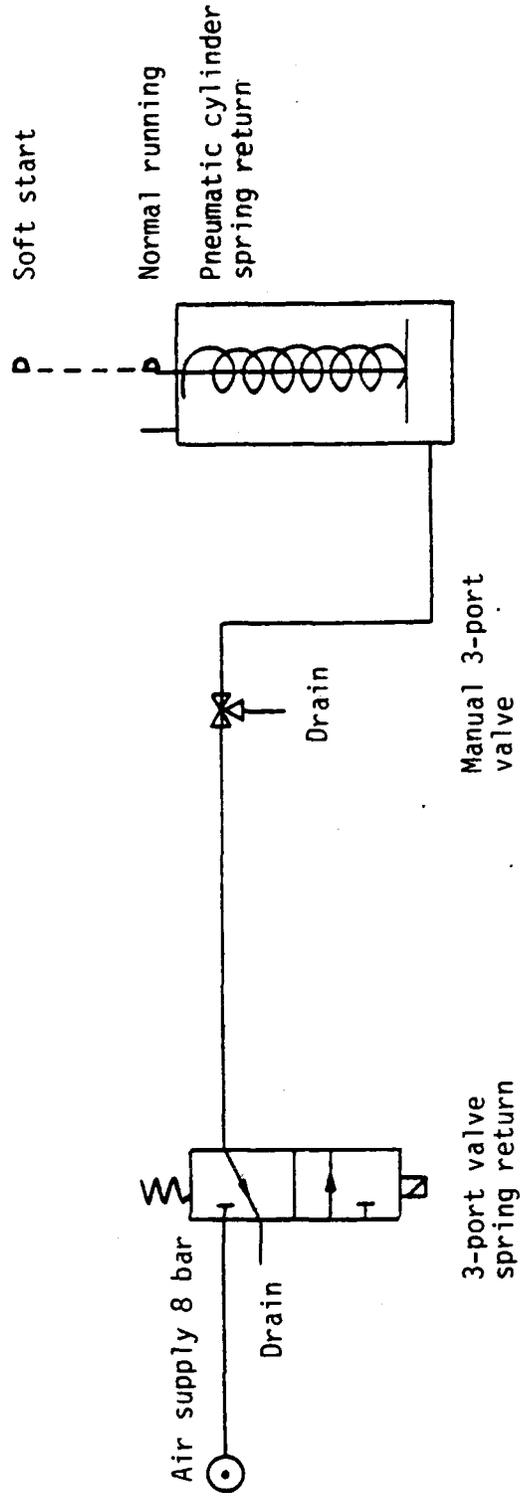


Figure 3. Mechanical equipment for soft start.

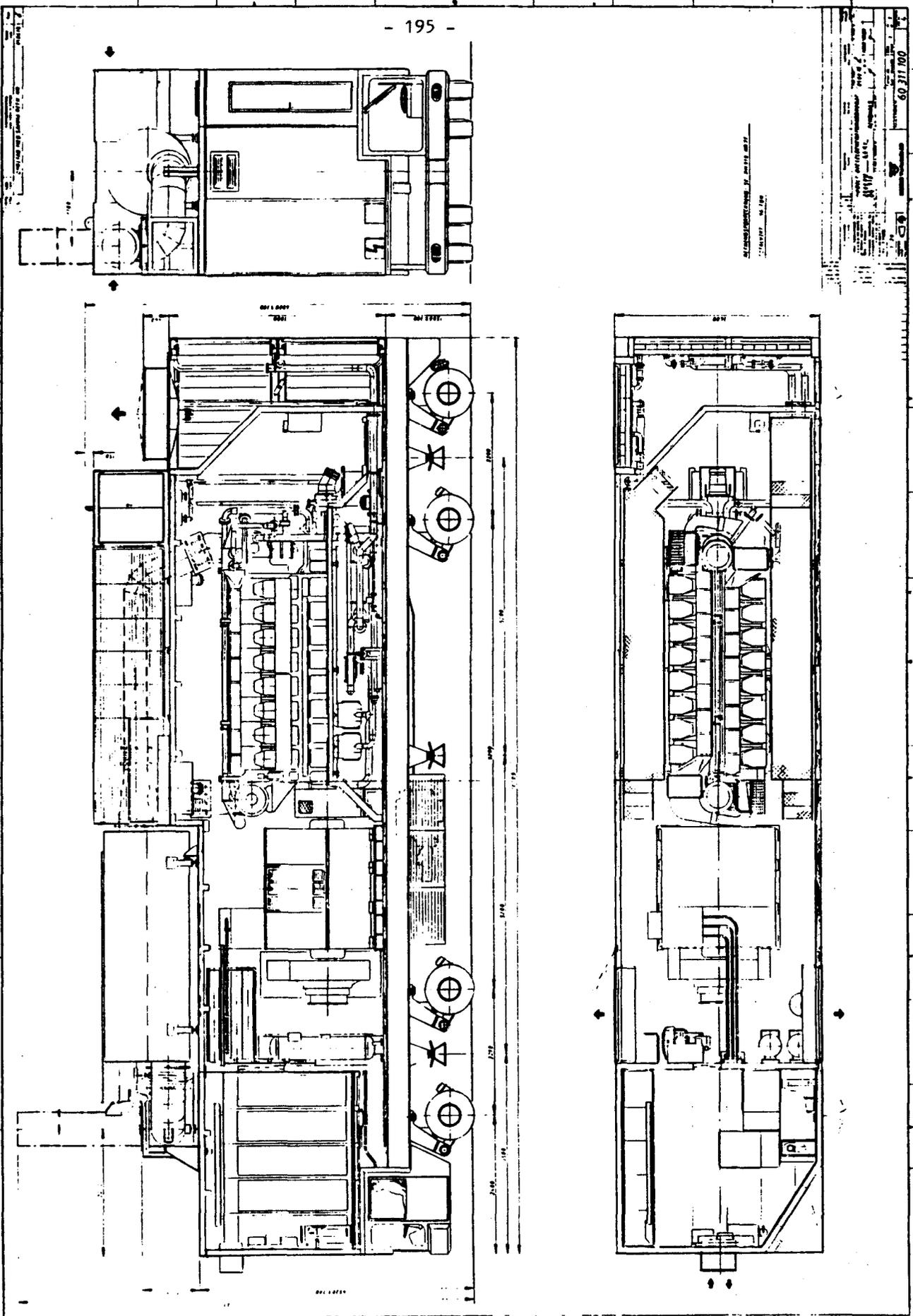


Figure 4. The mobile diesel generator set.