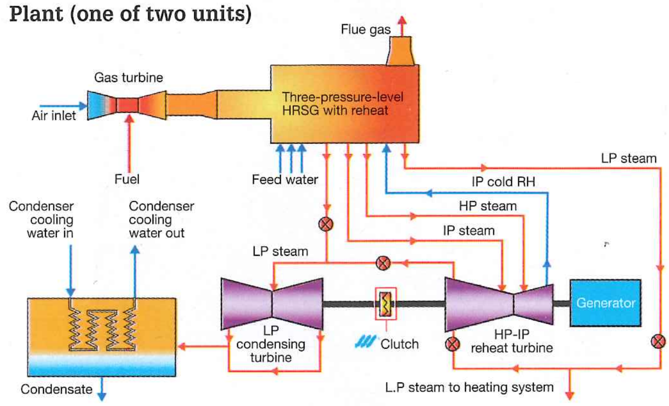
Engaging with CHP: how the SSS clutch increases flexibility

by James Varley

Visualisation of Seoul Combined Cycle Thermal Power Plants No. 1 and 2 site following project completion. The units are underground

System diagram of Seoul Combined Cycle Thermal Power Plant (one of two units)



The SSS (Synchro-Self-Shifting) clutch, which automatically engages and disengages through shaft speed control only, is an ingenious device widely used in combined cycle plants, eg to disconnect the steam turbine in a single shaft configuration, allowing the gas turbine/generator to be operated separately. The clutches are also proving valuable in combined heat and power applications, typically employed between steam turbine sections, greatly increasing operational flexibility.

A recent CHP application is in Korea Midland Power's remarkable new 2 x 400 MWe combined cycle power plant currently under construction below Seoul, in the Mapo district, to the west of the city. This has the distinction of being the world's first underground utility-scale fossil fuelled power station, with LNG as primary fuel.

As well as generating electricity – capable of meeting about 10% of Seoul's power demand – Seoul Combined Cycle Thermal Power Plants No. 1 and 2, will also supply heat (up to about 616 MW) to nearby offices, homes and public buildings.

Due to start up in 2017, the new CHP plant is being constructed by Posco with main equipment (gas and steam turbines plus heat recovery steam generators) supplied by MHI licensee Doosan.

The facility is located at (or rather under) the site of what was Korea's first fossil fired power plant. Seoul Thermal Power Plant units 1, 2 and 3, built in the 1930s and 1950s, were all demolished by 1982 with only the 380 MW units 4 and 5 remaining in operation in part of the site. Once the new combined cycle CHP facility is in operation, units 4 and 5 will be shut down and the site remodelled to include a park, sports facilities, performance spaces, library and observation platform integrated with the power plant chimneys. The excavation to accommodate the new power plant is 25 m (average depth) x 194 m x 164 m, with special attention paid to installation of watertight barrier walls due to the proximity to the Han River.

Savings in Seoul

The fuel cost for the Seoul CHP plant is put at about $10 per MMBtu, while the value of electricity generated is estimated to vary between around $150 and $450 per kWh.

In each unit the SSS clutch is located between the LP and HP/IP sections of the steam turbine (see system diagram, above). Why a SSS clutch in this case?

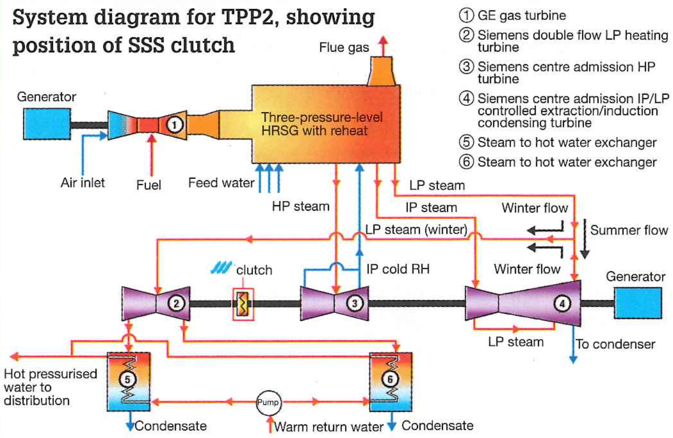
The LP turbine in the Seoul plant has a minimum steam flow of approximately 500 000 lb/h. During maximum heating load periods this steam is worth considerably more if sold for heating than the value of the electric power that could be generated with it via the LP section of the turbine.

It is estimated that on an annual basis use of the clutch provides an increased income of approximately $5 000 000.

An alternative to the clutch would be deploying a separate LP turbine with its own generator and switchgear, at an added equipment and construction cost of more than twenty times the cost of the clutch.

TPP2, one of two 400 MW CC CHP units at the site in Riga

System diagram for TPP2, showing position of SSS clutch



Riga rationale

Another notable combined cycle CHP plant that makes good use of the added operational flexibility provided by the SSS clutch is TPP2 in Riga, Latvia, one of two 400 MW CC CHP units at the site.

TPP2 (see system diagram) includes a GE Frame 9 gas turbine, three pressure level heat recovery steam generator with IP reheat, and a steam turbine train consisting of the following: Siemens double flow LP back pressure heating turbine; SSS clutch to engage/disengage the double flow LP back pressure heating turbine; Siemens centre admission HP turbine; and Siemens centre admission IP/LP controlled extraction/induction condensing turbine.

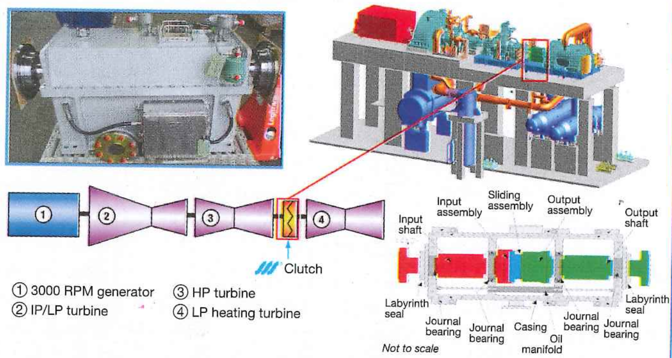
Steam conditions are: HP, up to 125 bara/545°C (1800 psia/1000°F); IP and IP reheat, up to 37 bara/545°C (537 psia/1000°F); LP, up to 3.5 bara/275°C (51 psia/525°F); condensing pressure, as low as 0.02 bara (0.3 psia). The plant output is 410 MWe in summer and 390 MWe plus 920 million Btu/h in winter.

Among operating requirements of the plant are that it generates almost the same amount of power in winter heating mode as it does in summer full condensing mode. And almost all of the low temperature heat lost in the condenser in the summer is recovered as high temperature condensing heat in the winter. This requires:

- different steam temperatures, pressures, and flows for the three levels of HRSG steam in the winter compared to summer;
- optimisation of the double flow LP back pressure heating turbine for the winter steam conditions;
- optimisation of the centre admission IP/LP, controlled extraction/induction condensing turbine for summer steam conditions; and
- a SSS clutch to allow the double flow LP back pressure heating turbine to be shutdown in summer and engaged to the train in winter.

MPS

Encased clutch, as employed in TPP2



Nuts and bolts of the SSS clutch

The initials "SSS" denote the 'Synchro-Self-Shifting' action of the clutch, whereby the clutch teeth are phased and then automatically shifted axially into engagement when input and output shaft are rotating at precisely the same speed. The clutch disengages as soon as the input speed slows down relative to the output speed.

The basic operating principle of the SSS clutch can be compared to the action of a nut screwed on to a bolt. If the bolt rotates with the nut free, the nut will rotate with the bolt. If the nut is prevented from rotating while the bolt continues to turn, the nut will move in a straight line along the bolt.

In a SSS clutch the input shaft (E) has helical splines (D) which correspond to the thread of the bolt. Mounted on the helical splines is a sliding component (C), which is analogous to the nut. The sliding component has external clutch teeth (B) at one end, and external ratchet teeth (G) at the other.

When the input shaft rotates, the sliding component rotates with it until a ratchet tooth contacts the tip of a pawl (A) on the output clutch ring (F) to prevent rotation of the sliding component relative to the output clutch ring. This position is shown in 1.

As the input shaft continues to rotate, the sliding component moves axially along the helical splines of the input shaft. When a ratchet tooth is in contact with a pawl tip, the clutch engaging teeth are perfectly aligned for inter-engagement and thus will pass smoothly into mesh in a straight line path.

As the sliding component moves along the input shaft, the pawl passes out of contact with the ratchet tooth, allowing the clutch teeth to come into flank contact and continue the engaging travel as shown in 2. Note that the only load on the pawl is that required to shift the lightweight sliding component along the helical splines.

Driving torque from the input shaft will only be transmitted when the sliding component completes its travel by contacting an end stop on the input shaft, with the clutch teeth fully engaged and the pawls unloaded as shown in 3.

When a nut is screwed against the head of a bolt, no external thrust is produced. Similarly when the sliding component of an SSS clutch reaches its end stop and the clutch is transmitting driving torque, no external thrust loads are produced by the helical splines.

Where necessary, an oil dashpot is incorporated in the end stop to cushion the clutch engagement.

If the speed of the input shaft is reduced relative to the output shaft, the torque on the helical splines will reverse. This causes the sliding component to return to the disengaged position and the clutch will overrun (or "freewheel").

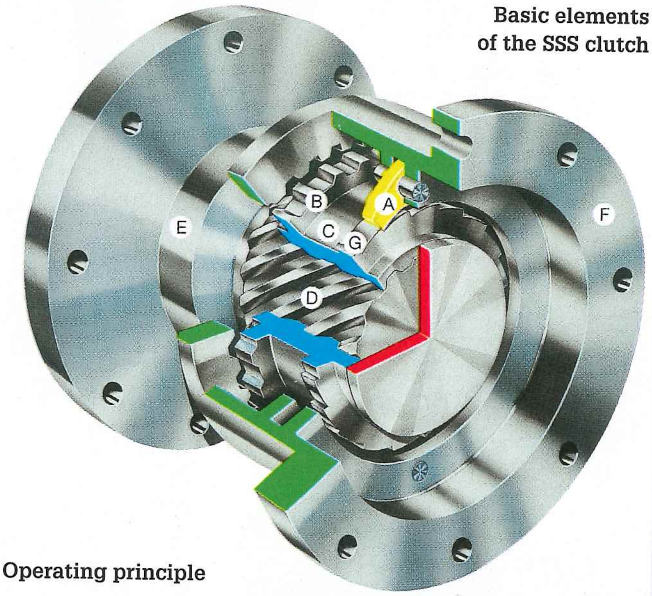
At high overrunning speeds, pawl ratcheting is prevented by a combination of centrifugal and hydrodynamic effects acting on the pawls.

The basic SSS clutch can operate continuously engaged or overrunning at maximum speed without wear occurring.

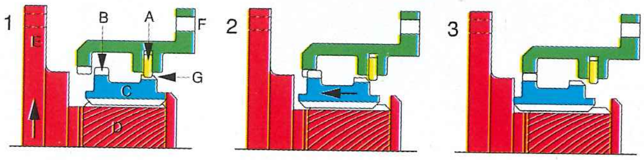
See also: YouTube clips, eg, www.youtube.com/watch?v=rOT4O-lwzu8, and www.youtube.com/watch?v=iA1o6aJehAg; and www.sssgears.com, How It Works.

As well as CHP and combined cycle applications, other uses include synchronous condensing and spinning reserve power plant, marine propulsion, petrochemical applications (pumps, fans and compressors) and turning gear drives.

Basic elements of the SSS clutch



Operating principle



A – pawl; B – main driving teeth; C – helical sliding component; D – helical spline; E – input; F – output; G – ratchet teeth