Simple Cycle (SC) Operation at Combined Cycle (CC) Plants

Disadvantages of SC over CC:

- Less MW output
- Worse Heat Rate
- May require Hot SCR to meet air permit requirements, adding significantly to installed cost and auxiliary load.

Advantages of SC over CC:

- Faster and cheaper to install
- Less complicated and less equipment, requiring fewer staff to operate
- Faster startups and shutdowns

Means to have SC operation at CC plants:

- Dedicated SC units, separate from the CC plant
- Steam turbine bypass to condenser at full output from the gas turbine
- Diverter dampers for HRSG bypass.
Steam Bypass to Condenser

Most CC plants are designed to operate in steam bypass mode during start-ups to allow the steam turbine and other equipment to warm up at a controlled rate, usually with the gas turbine at part-load. Many condensers are also ‘designed’ or ‘rated’ for “full flow steam turbine bypass”. However, in practice, few condensers are actually capable of frequent or sustained full steam bypass operation for long periods at maximum gas turbine output, without incurring damage.

TVA Lagoon Creek CC condenser sparger damaged during steam bypass operation (steam blows with gas turbine at Full Speed No Load)
Diverter Dampers
Purge Requirements for Diverter Damper Arrangements

For SC-only operation, only the SC exhaust system is purged and the damper remains in the SC position (i.e. ‘bypass position’) from start-up to shutdown. Similarly for CC-only operation, the HRSG system is purged and the damper remains in the CC position from start-up to shutdown. However, NFPA 85 Code says in Section 8.9.2.1 (Ref CT Exhaust Bypass Systems):

"A purge of both the HRSG enclosure and the bypass system shall be completed prior to the admission of combustion turbine exhaust gas into the HRSG"

This is open to interpretation and can be taken to mean that separate purges of the simple cycle exhaust system and the HRSG system must be completed prior to any unit operation in which a transition may be made from CC to SC mode. GE takes this as their official position and refuses to implement controls arrangement to their diverter dampers that would allow a transfer from CC to SC ‘on the fly’ unless separate purges of CT and CC systems (i.e. with the damper in both positions) have been performed prior to unit operation - either during startup or from the previous shutdown if "Purge Credit” conditions (described in NFPA 85 Section 8.8.4.6) have been met.

A gas turbine with dual fuel further complicates the purging requirements of a diverter damper arrangement. This is because the autoignition temperature of distillate fuel oil is about 410 DegF (versus about 1,070 DegF for natural gas). To meet NFPA 85, purging air must be at least 100 DegF below the lowest autoignition temperature of either fuel. So, to meet HRSG purge requirements during operation, diverter damper transitions can usually only be made from CC to SC mode, not the other way. In other words, for CC operations, the unit must be started with the damper in the CC position and it cannot be started in SC position and transferred to CC mode with flame in the gas turbine UNLESS all the conditions for ‘Purge Credit’ (noted in NFPA 85 Section 8.8.4.6) have already been met from the previous unit shutdown.

CEMS Requirement on Diverter Damper Arrangements

Most air permits in the US require CEMS on each exhaust stack. So a unit train with separate SC and CC (HRSG) stacks, requires two sets of CEMS. Air permits are also usually written with separate limits on emissions and operating time in SC mode and, if dual fuel, also on the secondary fuel. For transitions between CC and SC operation, the air permit will usually define each operating mode for CEMS datalogging and emissions reporting purposes. The position of the diverter damper, as indicated by a limit switch signal, is sometimes used for this purpose. This prevents the need to report simultaneous emissions from both stacks - which might occur if there is zero error on one CEMS system or if there is damper leakage during unit operation.
Most HRSGs have an SCR to reduce the NOx level of the gas turbine exhaust to below CC permit level before it exits the HRSG stack. SCR catalysts work best between a temperature range of 600-800 DegF and this is typically within the steady-state exhaust temperature range inside the HRSG. However, steady state gas turbine exhaust temperature can be as high as 1,200 DegF at maximum load, which is well above SCR catalyst operating temperature limit. The only currently-available option to accommodate this is to dilute the hot gas turbine exhaust stream with large amounts of cooler air to reduce its temperature before passing into an SCR. But this arrangement is expensive to purchase and install (up to 50% of the cost of the gas turbine) and there are significant auxiliary power costs associated with operating the large air compressors/blowers required for it.
Reducing Gas Turbine Output to Meet Simple Cycle Emission Limits

Gas turbine OEM combustion system design improvements in the past generally reduced simple cycle NOx and CO production. However, serial improvements to output and efficiency have also required increasing firing temperatures which, in turn, have tended to increase NOx production. As most large frame gas turbines (F-Class and above) are used in Combined Cycle applications - with their SCRs and CO catalysts - most OEMs do not consider design simple cycle emissions for these machines to be as important as their design output and heat rate. This has recently led to a reversal of the historical trend to reduce NOx ppm emissions and this has made simple cycle/diverter damper operation of these units more difficult to permit without installing simple cycle (hot) SCRs. One way to reduce simple cycle emissions is to slightly reduce firing temperature and load specifically for simple cycle operation. While this will not allow simple cycle NOx emissions to meet the low permit levels in some states, it currently does in (Ozone Attainment areas) in all the TVA states.