

CLAIMS

1. A drive system for liquefied natural gas (LNG) refrigeration compressors in a LNG liquefaction plant, comprising:

first, second, and third refrigeration compression strings, each refrigeration compression string including

one or more refrigeration compressors, and

a multi-shaft gas turbine capable of non-synchronous operation, the multi-shaft gas turbine being operationally connected to the one or more refrigeration compressors and configured to drive the one or more refrigeration compressors, wherein the multi-shaft gas turbine uses its inherent speed turndown range to

start the one or more refrigeration compressors from rest,

bring the one or more refrigeration compressors up to an operating rotational speed, and

adjust compressor operating points to maximize efficiency of the one or more refrigeration compressors,

without assistance from electrical motors with drive-through capability and variable frequency drives;

wherein the first refrigeration compression string is configured to provide compression to a propane refrigerant, the second refrigeration compression string is configured to provide compression to a mixed refrigerant, and the third refrigeration compression string is configured to provide compression to a nitrogen refrigerant.

2. The drive system of claim 1, further comprising a waste heat recovery unit that extracts heat from exhaust gases of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings, thereby increasing overall energy efficiency of the LNG liquefaction plant.

3. The drive system of claim 1 or claim 2, further comprising an inlet air chilling apparatus configured to chill air entering an inlet of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings, thereby maximizing natural gas throughput and/or efficiency of the LNG liquefaction plant.

4. The drive system of claim 3, wherein the inlet air chilling apparatus comprises a mechanical refrigeration system that is independent of the first, second, or third refrigeration compression strings.

5. The drive system of claim 3, wherein the inlet air chilling apparatus comprises a mechanical refrigeration system that is integrated with at least one of the first, second, or third refrigeration compression strings, wherein the air entering the inlet of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings is chilled using refrigerant compressed by one or more of the refrigeration compressors of the first, second, or third compression strings.

6. The drive system of any of claims 1-5, wherein operation of all of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings is required for natural gas liquefaction.

7. The drive system of any of claims 1-5, wherein operation of only two of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings is required for natural gas liquefaction.

8. The drive system of claim 7, wherein the first refrigeration compression string is further configured to provide compression to the mixed refrigerant, the second refrigeration compression string is further configured to provide compression to the propane refrigerant, and wherein operation of

only one of the multi-shaft gas turbines of the first refrigeration compression string and the second refrigeration compression string, and

the multi-shaft gas turbine of the third refrigeration compression string, is required for natural gas liquefaction.

9. The drive system of any of claims 1-5, wherein the first refrigeration compression string is further configured to provide compression to the mixed refrigerant, the second refrigeration compression string is further configured to provide compression to the propane refrigerant, and wherein operation of only two of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings is required for natural gas liquefaction.

10. The drive system of any of claims 1-9, wherein a refrigerant compressed by at least one of the refrigeration compressors of at least one of the first, second, or third refrigeration compression strings is cooled by air.

11. The drive system of any of claims 1-10, wherein a refrigerant compressed by at least one of the refrigeration compressors of at least one of the first, second, or third refrigeration compression strings is cooled by water.
12. The drive system of any of claims 1-11, wherein at least one of the first, second, and third refrigeration compression strings includes an electrical generator that converts excess turbine mechanical power to electricity and exports the electricity to an electrical grid.
13. The drive system of any of claims 1-12, wherein each multi-shaft gas turbine of the first, second, and third refrigeration compression strings has a rated output capacity of at least 70 megawatts.
14. The drive system of claim 1, wherein one or more refrigeration compressors of one of the first, second, and third compression strings assists compression work of another of the first, second, and third compression strings.
15. A method of producing liquefied natural gas (LNG), comprising:
 - arranging each of first, second, and third refrigeration compression strings to include one or more refrigeration compressors and a multi-shaft gas turbine operationally connected to the one or more refrigeration compressors;
 - using the multi-shaft gas turbine in each of the first, second, and third refrigeration compression strings, driving the respective one or more refrigeration compressors using a non-synchronous operation;
 - providing compression to a propane refrigerant using the first refrigeration compression string;
 - providing compression to a mixed refrigerant using the second refrigeration compression string;
 - providing compression to a nitrogen refrigerant using the third refrigeration compression string;
 - without assistance from electrical motors with drive-through capability or variable frequency drives, using an inherent speed turn-down range of at least one of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings to
 - start the one or more refrigeration compressors from rest,
 - bring the one or more refrigeration compressors up to an operating

rotational speed, and

adjust compressor operating points to maximize efficiency of the one or more refrigeration compressors.

16. The method of claim 15, further comprising:

extracting heat from exhaust gases of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings using a waste heat recovery unit.

17. The method of claim 15 or claim 16, further comprising:

chilling air entering an inlet of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings.

18. The method of claim 17, wherein chilling the air comprises:

chilling the air entering the inlet of the multi-shaft gas turbine using an inlet air chilling apparatus comprising a mechanical refrigeration system that is independent of the first, second, or third refrigeration compression strings.

19. The method of claim 17, wherein chilling the air comprises:

chilling the air entering the inlet of the multi-shaft gas turbine of at least one of the first, second, and third refrigeration compression strings using refrigerant compressed by one or more of the refrigeration compressors of the first, second, or third compression strings.

20. The method of any of claims 15-19 wherein operation of all of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings is required for natural gas liquefaction.

21. The method of any of claims 15-19, wherein operation of only two of the multi-shaft gas turbines of the first, second, and third refrigeration compression strings is required for natural gas liquefaction.

22. The method of claim 21, further comprising:

providing compression to the propane refrigerant and the mixed refrigerant using the first refrigeration compression string; and

providing compression to the propane refrigerant and the mixed refrigerant

using the second refrigeration compression string;
wherein operation of only two of
the multi-shaft gas turbines of the first refrigeration compression string
and the second refrigeration compression string, and
the multi-shaft gas turbine of the third refrigeration compression string,
is required for natural gas liquefaction.

23. The method of any of claims 15-19, further comprising:
providing compression to the propane refrigerant and the mixed refrigerant
using the first refrigeration compression string; and
providing compression to the propane refrigerant and the mixed refrigerant
using the second refrigeration compression string;
wherein operation of only two of the multi-shaft gas turbines of the
first, second, and third refrigeration compression strings is required for natural gas
liquefaction.

24. The method of any of claims 15-23, further comprising:
air-cooling a refrigerant compressed by at least one of the refrigeration
compressors of at least one of the first, second, or third refrigeration compression strings.

25. The method of any of claims 15-24, further comprising:
water-cooling a refrigerant compressed by at least one of the refrigeration
compressors of at least one of the first, second, or third refrigeration compression strings.

26. The method of any of claims 15-25, further comprising:
converting excess turbine electrical power of the multi-shaft gas turbine of at
least one of the first, second, and third refrigeration compression strings into electricity
using an electrical generator, and
exporting the electricity to an electrical grid.

27. The method of any of claims 15-26, further comprising:
moving one or more compression stages of a refrigeration compressor in one of
the first, second, or third compression strings, to another of the first, second, or third
compression strings, to thereby assist compression work of the one of the first, second,
or third compression strings.