IDEA's 28th
Annual Campus Energy Conference
CAMPUS ENERGY 2015
Clean Energy for the Next Generation
Denver, CO

Overrunning Clutches in Dual Driven Turbine & Chiller Trains to Reduce CAPEX, Lower Operating Costs and Increase Operating Flexibility

James Berry & Morgan Hendry
February 10, 2015

Clutch Company, Inc.

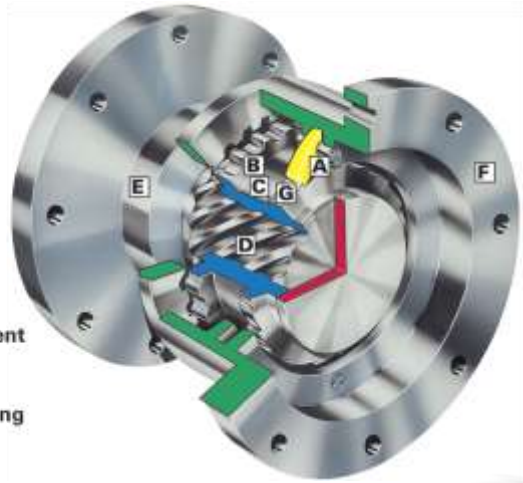
Basic Clutch for CHP Application - How Does it Work?

It can be called…

- Freewheel
- Overrunning Clutch
- One Way Clutch

It is…

- Mechanical
- Automatic



Elements of Basic SSS Clutch

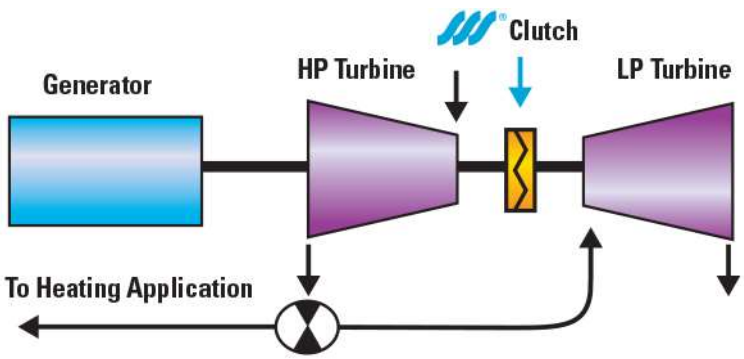
A. Pawl
B. Clutch Teeth
C. Sliding Component
D. Helical Splines
E. Input Shaft
F. Output Clutch Ring
G. Ratchet Teeth

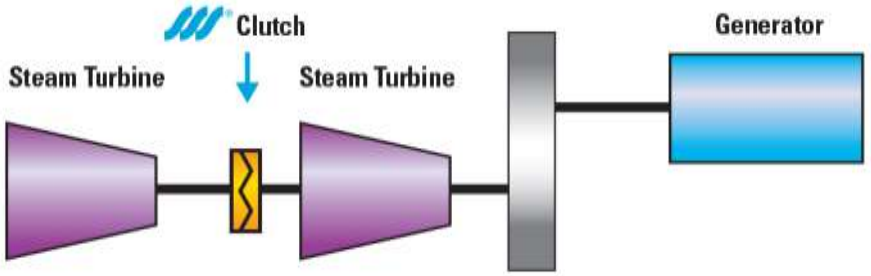
Overrunning Clutches in District Energy Systems

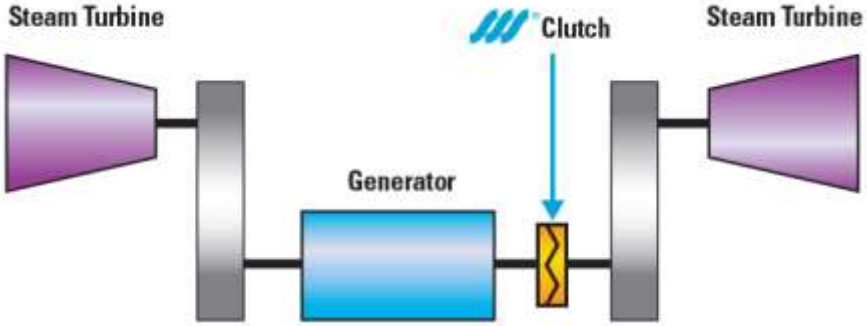
Applications

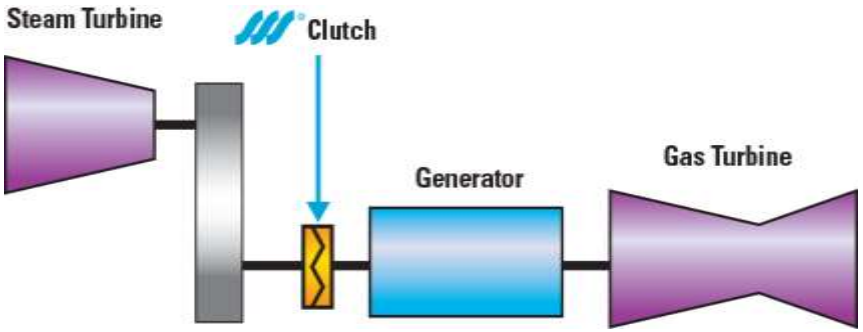
- LP-HP Steam Turbine Generator Trains
- Single-Shaft, Combined-Cycle Trains
- Synchronous Condensing
- Energy Storage
- Dual Driven Chillers
- Dual Driven Pumps and Fans
- Gas Turbine Starter Clutches
- Turning Gear Clutches

Clutch Arrangements — Single-Shaft CHP Applications







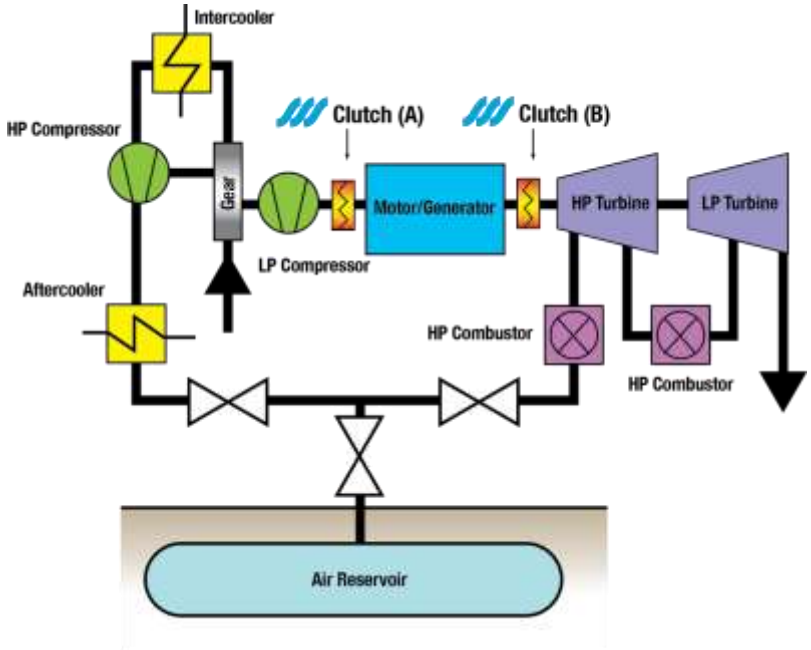


Clutches for Compressed Air Energy Storage

(CAES) Plant — McIntosh, Alabama

55MW @ 3600 RPM Compressor SSS® Clutch

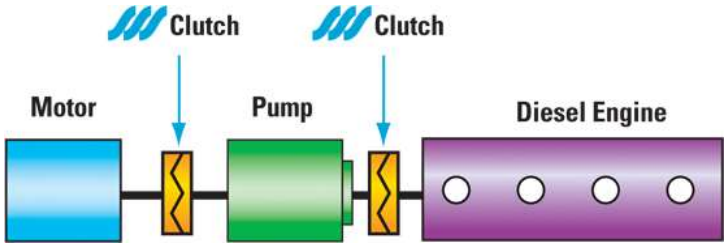
114MW @ 3600 RPM SSS® Expander Turbine Clutch



Recent Clutch Inquiries for 10-20MW Above Ground CAES and LAES (Liquid Air Energy Storage) Applications

Clutches for Dual Driven Water Pumps

Municipal Water Pump — Boca Raton, Florida



Size 30 Encased SSS® Clutches connect 600 hp, 1185 rpm diesel engine and electric motor to dual driven Municipal Water Pump.

This concept could be applied to a large chilled water circulating pump

Case Study 1
Clutches for CHP Plant Application

Combined Heat and Power Facility — Plauen, Germany

Challenge: Economically generate power with a steam turbine by recovering energy lost in a let down valve in a district energy fired boiler steam plant with wide swings in steam flow.

Background: Plant is one of three that serve 14,000 households, office buildings, a hospital, and manufacturing facilities. original plant built in 1988 provided heat only until an upgrade in 2000.

Conditions: **Flow variation** from 132,000 lbs/hr to 10,000 lbs/hr with 80% of the time under 100,000 lbs/hr and 25% under 33,000.
Steam at turbine inlet: 12.7 bar ~ 300˚ C,
Steam conditions at turbine exhaust: 5.7 bar, ~ 250˚ C

Case Study 1
Clutches for CHP Plant Application

Combined Heat and Power Facility — Plauen, Germany

Alternative: One special geared multi-valve 2-stage turbine generator designed for the 132,000 lbs/hr

Problem: Too expensive; efficiency poor under half load; would not meet required pay-back time

Alternative: One standard single valve steam turbine generator with automated hand valves

Problem: Least expensive alternative but overall very poor efficiency over the required operating range; would not meet required pay-back time

Alternative: Two relatively inexpensive standard single valve turbines with automated hand valves each geared to a separate generator, one designed for 100,000 lbs/hr and the other for 33,000 lbs/hr

Problems: Two generators, and two sets of switchgear—an improvement in cost over the special turbine but still did not meet required pay-back period

Need to synchronize generator with the grid many times per day during the winter time as steam load varies often from 80,000 to over 100,000 lbs/hr

Difficult to fit in the available space

Case Study 1
Clutches for CHP Plant Application

Combined Heat and Power Facility — Plauen, Germany

Alternative: Two standard single valve turbines with automated hand valves both geared to a single double end drive generator through standard SSS® Clutch Couplings, one turbine designed for 100,000 lbs/hr and the other for 33,000 lbs/hr

NO Problems: Overall cost lower than the two turbines driving separate generators each with their own switchgear

Fits in the available space

Generator stays synchronized with the grid continuously

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Case Study 1
Clutches for CHP Plant Application

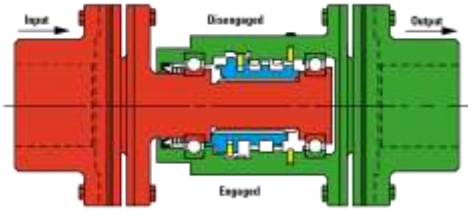
Combined Heat and Power Facility — Plauen, Germany

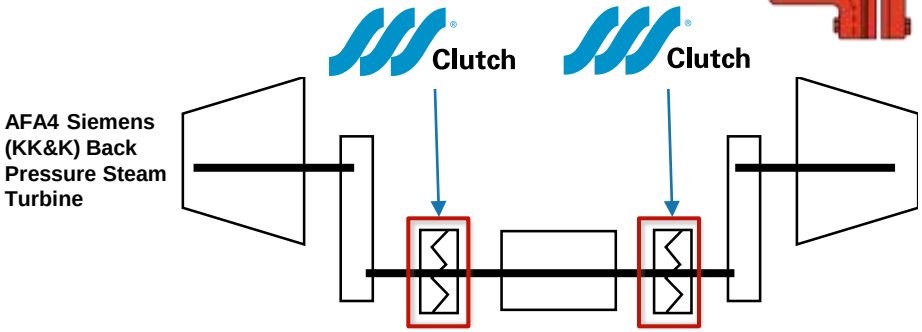
Steam
- 60 tonnes/hour grid
- 5.7 Bar pressure to grid
- 240 ° C temp to grid

Electricity
- 1.0 MWe back pressure turbine
- 0.32 MWe back pressure turbine
- 1,500 rpm generator

SSS® Clutches
- 36 + 30 SSS® Clutch Couplings
- No oil supply required
- Includes flexible couplings
- Size 30 includes electrical insulation

Siemens (KK&K) Dual Driven Steam Turbine Generator





1500 rpm Generator

Case Study 2
Overrunning Clutch Applications in District Energy Systems

Arizona State University 9 MW Combined Heat and Power Facility

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Case Study 2
Overrunning Clutch Applications in District Energy Systems

Arizona State University 9 MW Combined Heat and Power Facility

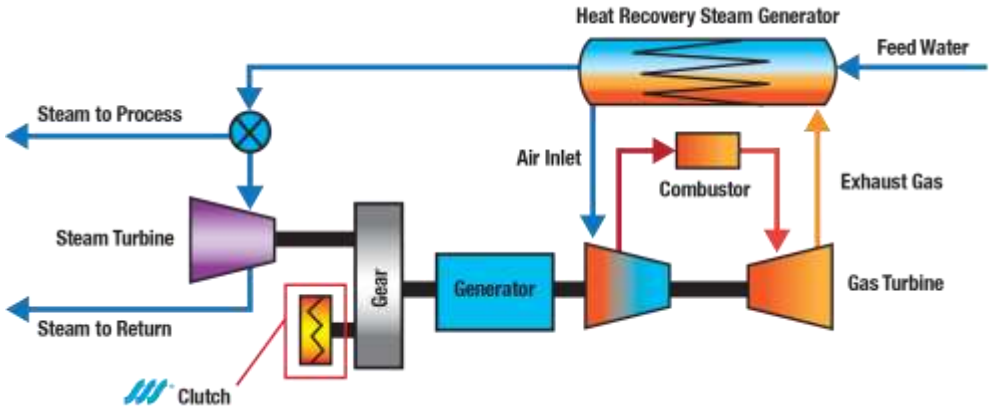
1–9 MW Solar Turbines STAC System Single Shaft Combined Cycle Power Train (Single Skid Package) Including:

- 1-Solar Turbines Taurus 70 7.5 MW Gas Turbine
- 1-Dresser-Rand 2 MW steam turbine
- 1-SSS® Gear type self-synchronizing overrunning clutch integrated into gearbox between…
- 1-10 MW double end drive generator
- 1-Set of switchgear
- 1-Combined GT-ST control panel

Case Study 2
Overrunning Clutch Applications in District Energy Systems

Arizona State University 9 MW Combined Heat and Power Facility

STAC System Schematic



STAC System Installation

Case Study 2
Overrunning Clutch Applications in District Energy Systems

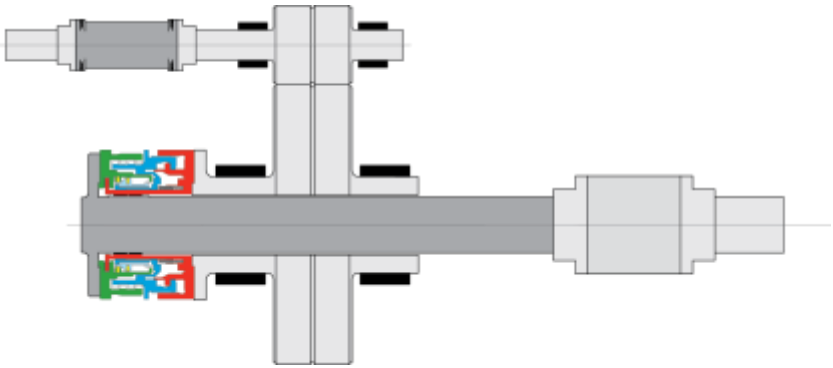
Arizona State University 9 MW Combined Heat and Power Facility

Areas of Cost Savings

- One 10 MW double end drive generator approximately **80% the cost** of the two separate generators
- One set of switchgear versus two – about **40% savings** compared to one for the GT and one set for the ST
- **Single skidded package** to handle and install versus two separate skids
- One run of generator power cabling
- **One combined GT and ST control panel** to install versus two separate panels
- **Installation space savings:** approximately 150 Ft^2 in power room plus 24 Ft^2 in control/switchgear area

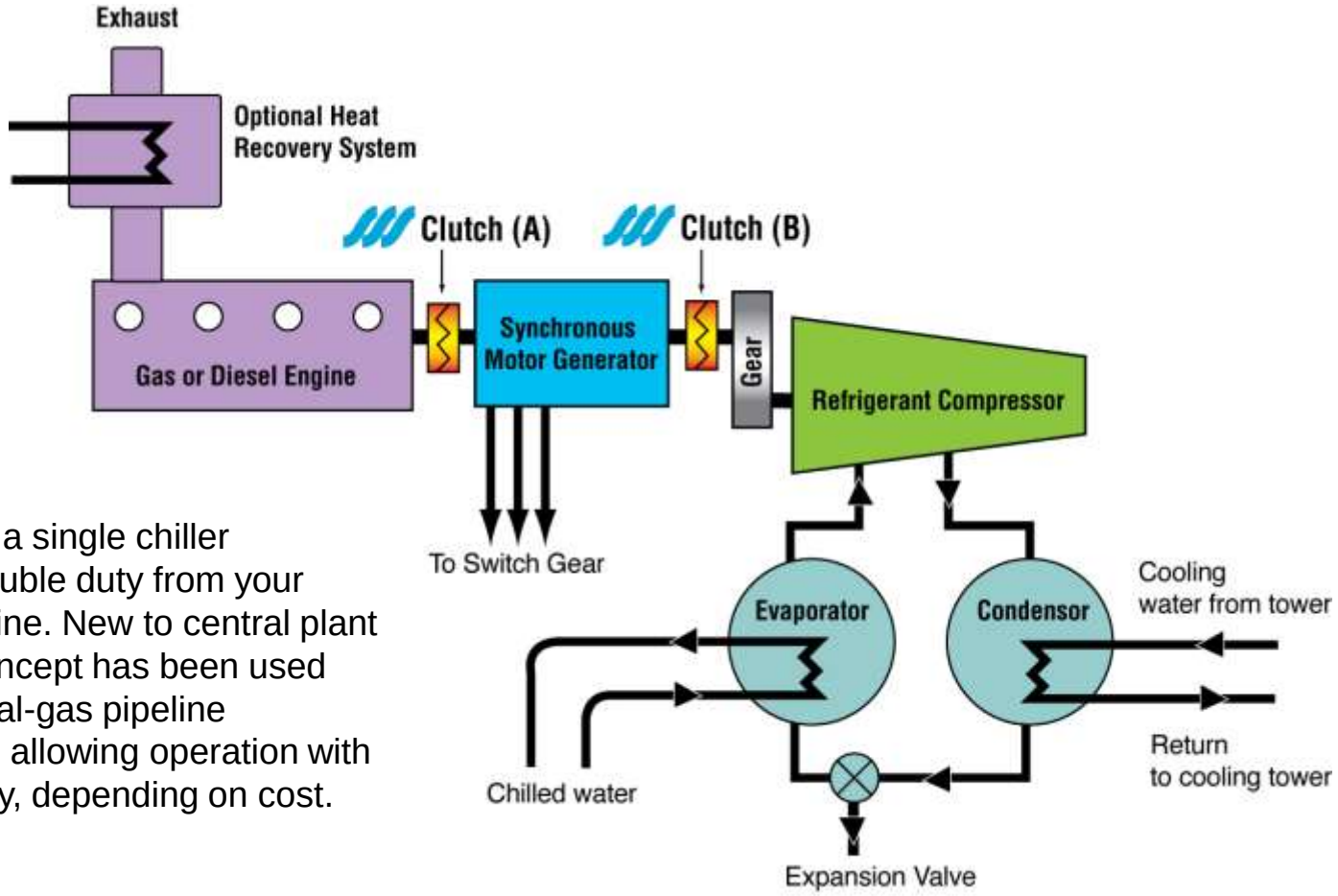
18 of the STAC packages with SSS® overrunning clutches have been installed around the world, some with encased clutches mounted between the steam turbine and generator and others with the clutch integrated in the gearbox.

Arrangement for Case Study 2 — Clutch Integrated with Gear



Clutch quill-shaft mounted with internal bearing

Clutches for Dual Driven Chillers



Connect two drivers to a single chiller compressor, getting double duty from your standby generator engine. New to central plant chiller systems, this concept has been used successfully with natural-gas pipeline compressors for years, allowing operation with natural gas or electricity, depending on cost.

Clutches for Dual Driven Chillers

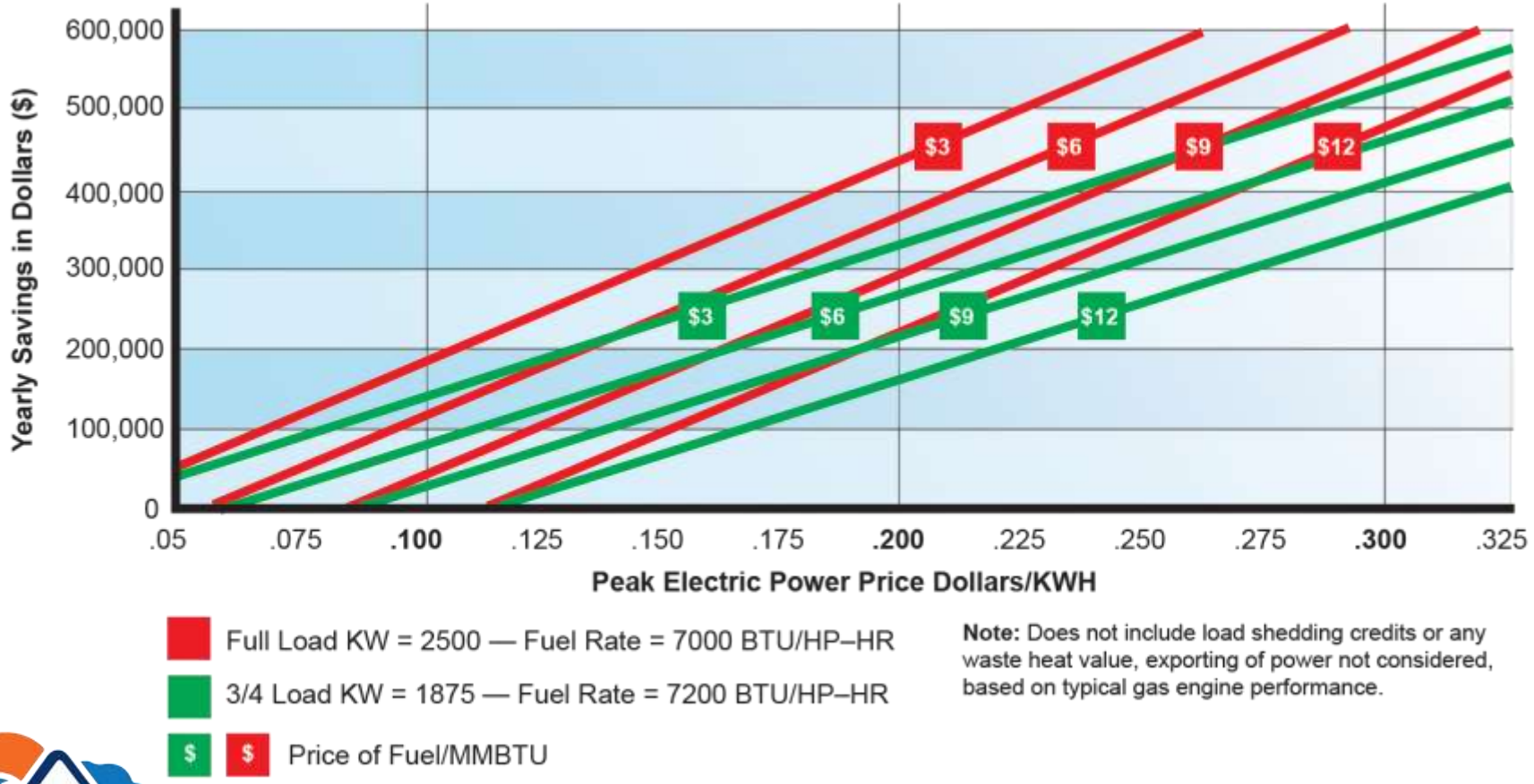
Modes of Operation for Chiller Systems:

MODE	CLUTCH A	CLUTCH B	ENGINE	MOTOR GENERATOR	COMPRESSOR
Off-peak refrigeration	Disengaged over-running	Engaged	Shut down	Running as motor	Running
On-peak refrigeration with motor load shedded or reduced for demand response	Engaged	Engaged	Running	Spinning with breaker open, or breaker closed and running at part load as motor	Running
Emergency refrigeration	Engaged	Engaged	Running	Spinning with breaker open	Running
Stand-by power generation	Engaged	Disengaged locked-out with pneumatic servo	Running	Running as generator	Shut down
Stand-by refrigeration and power generation (or on-peak refrigeration plus additional demand response by generating electric power to further reduce total facility demand)	Engaged	Engaged	Running	Running as generator	Running

Clutches for Dual Driven Chillers

2500 KW Dual Driven Chiller—Energy Cost Savings

Based on operating gas engine during 1000 on peak electric hours per year



Note: Does not include load shedding credits or any waste heat value, exporting of power not considered, based on typical gas engine performance.

Clutches for Dual Driven Chillers

Economic Benefits of Dual Driven Chillers

- Energy source selection based on real time costs
- Demand side management revenue
- Peak time power sales revenue
- Demand peak management
- Provides chilling during electric power outage
- Provides standby power during electric power outage
- Cost savings compared to separate standby generator and motor driven chiller
- Engine exhaust and jacket water can provide valuable heat

Energy Transfer's 4 MW "E-Select" Dual Driven Pipeline Compressor

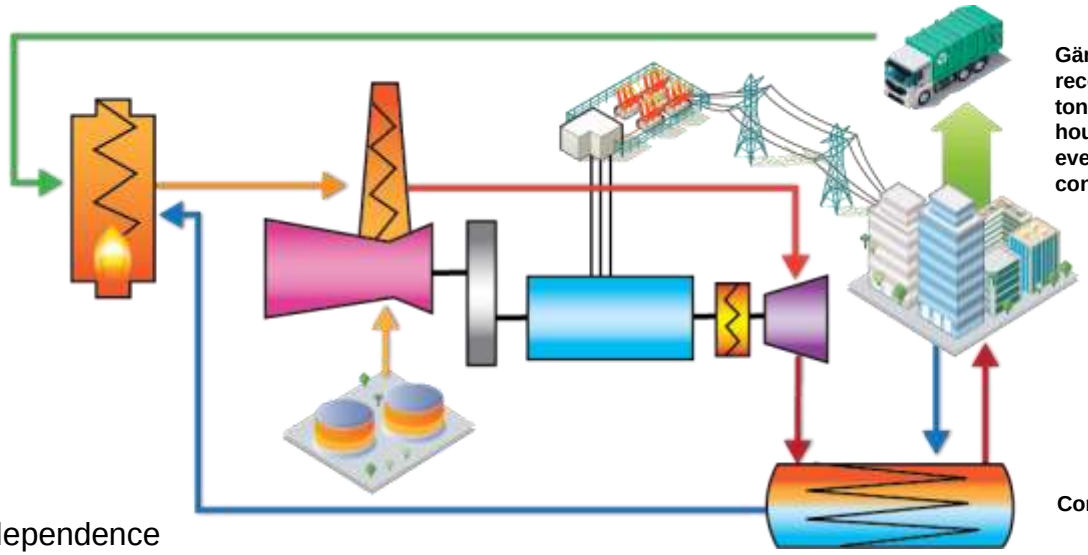
Household Waste for Pre-Heat Steam - Eliminate Landfill

Gärstad CHP — Linköping – Sweden

Steam
- 2,500 cu.m/hour grid
- 85 MWth power heat
- 49,000 households
- 20 ˚ C temp to grid

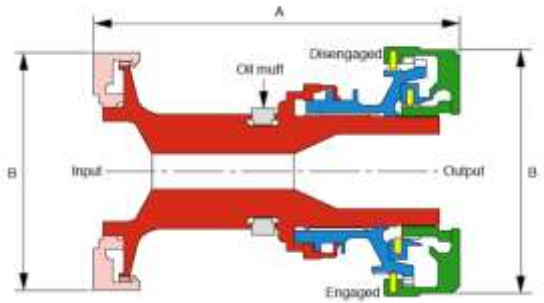
Electricity
- 26.7 MWe ABB ST
- 29 MWe GT10 ABB GT
- 3,000 rpm generator

SSS® Clutches
- 200 FT Spacer Type
- Disabled pawls allow TG independence
- Internal journal bearing
- 14 mm axial expansion capability
- Built in safeset coupling
- SSS® Pinion Clutch for TG operation



Gärstad CHP receives 200,000 tonnes of sorted household waste every year for steam condensate preheat

Condenser



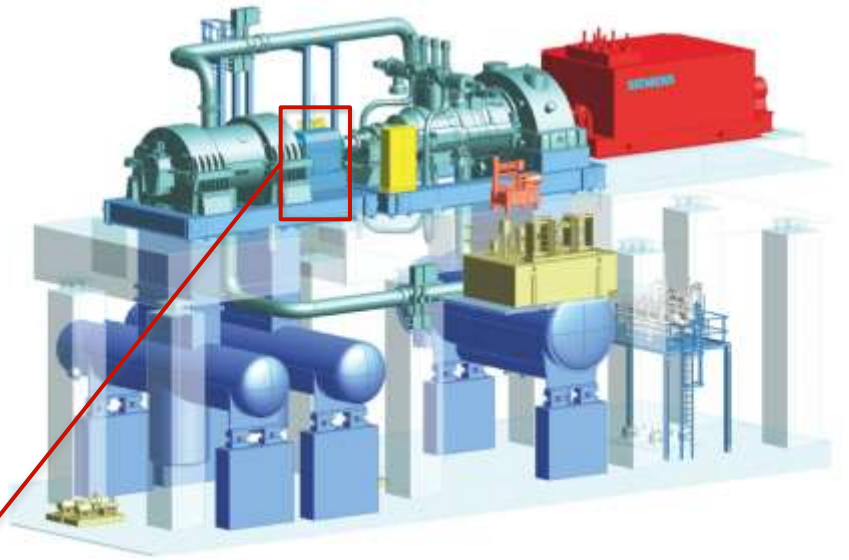
Wood Chip Fired Boiler with Process Steam for Paper Mill

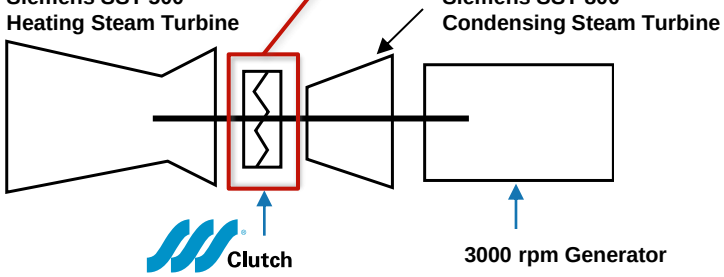
UPM/Siemens Goerlitz "KauVo" — Lappreenranta, Finland

Steam
- 295 cu.m/min paper mill
- 385 MW Total power:
  - 110 MWth district heat
  - 150 MWth process steam
  - 125 MWe electrical power
- 16.5 + 12 + 4.5 Bar pressure to paper mill
- 547° C temp to paper mill

Electricity
- 95 + 30 MWe Condensing Turbine
- 20 MWe Back Pressure Turbine
- 3,000 rpm generator

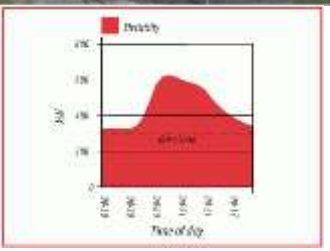
SSS® Clutches
- 140T Encased + 4 bearings
- Bearing temperature RTD's
- Vibration instruments

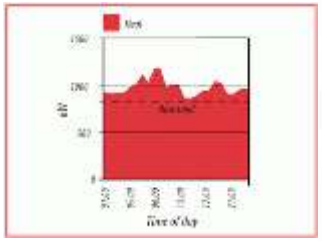


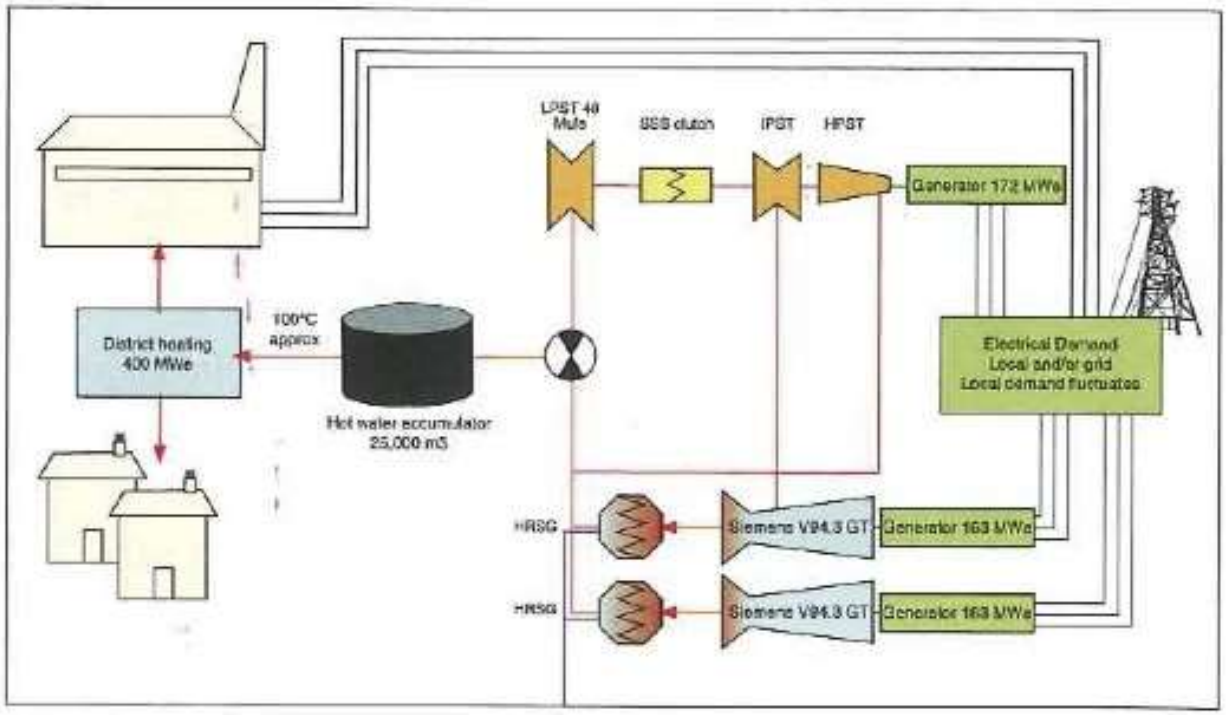


Size 140T SSS Encased Pressure Lubricated Clutch

Daily Cycling at Helsinki – Electricity & District Heating - Finland

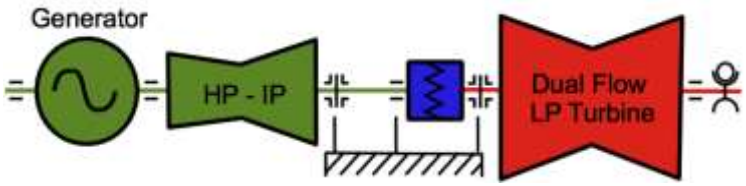






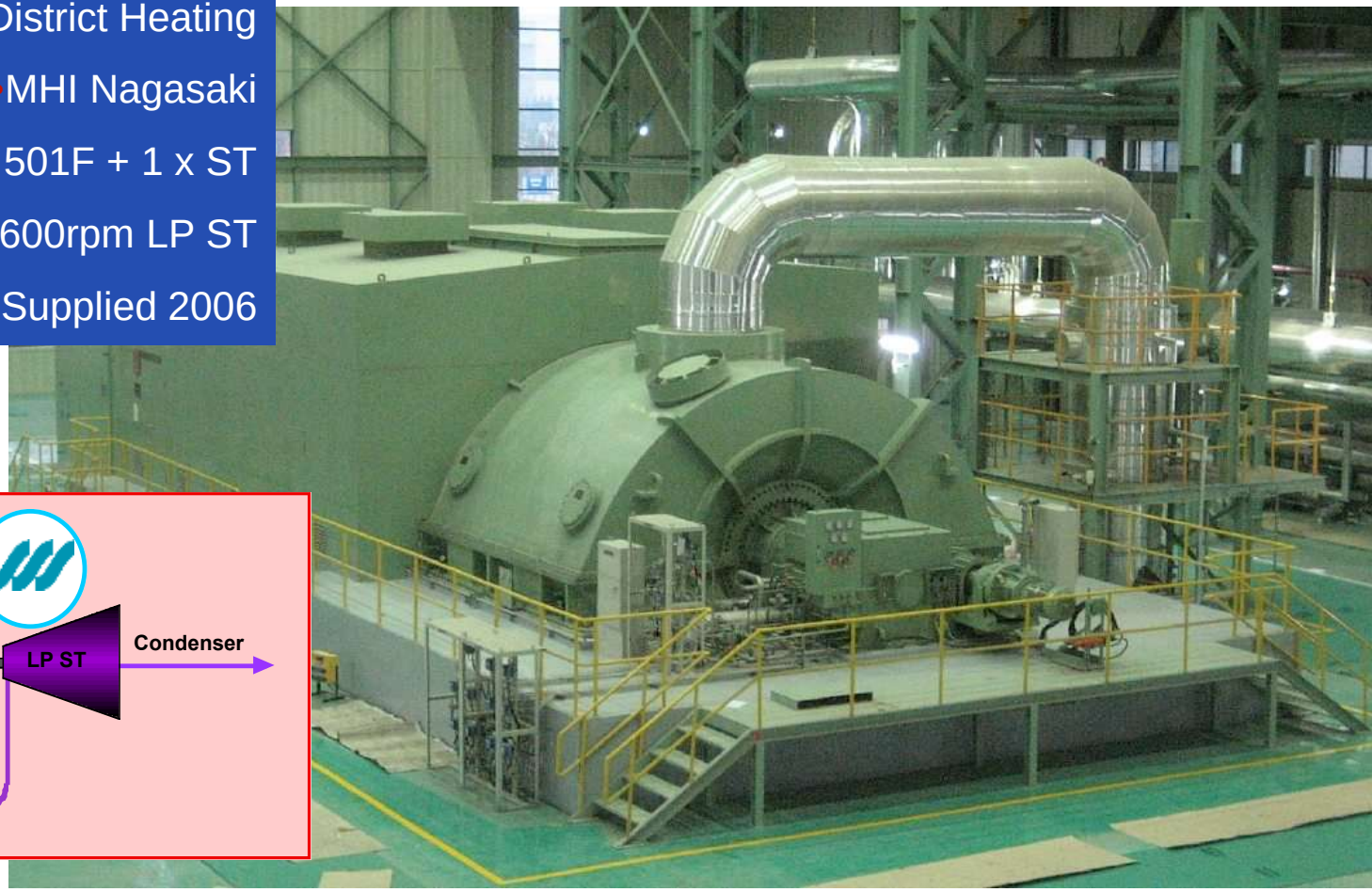
Vuosaari B : 1997 2+1

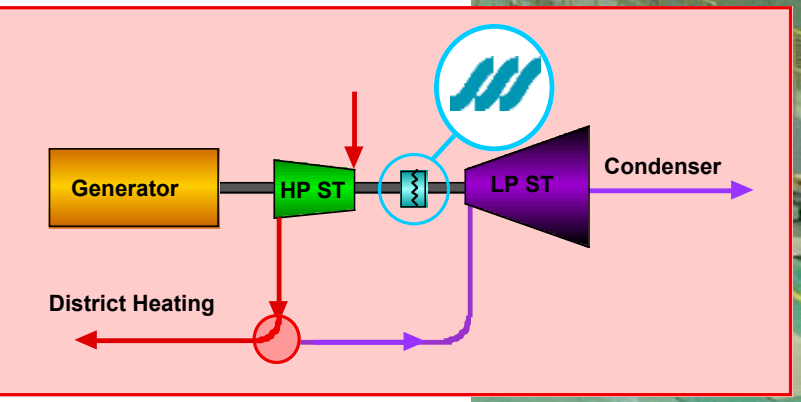
- 92% Efficiency
- 470MW Electricity 400MW district heat
- 25,000 m^3 water storage at 100˚C



CHP Application with Single-Shaft

- Korea District Heating
- MHI Nagasaki
- 2 x 501F + 1 x ST
- 97MW/3600rpm LP ST
- Supplied 2006

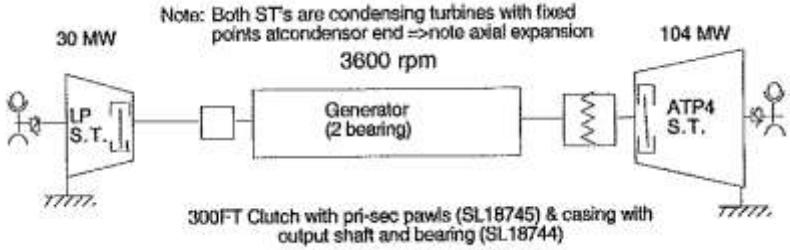




TransAlta's 650 MW Sarnia Regional Cogeneration Plant Largest in Canada

Commissioned in 2003, plant has three Alstom 11N2 gas turbines, each capable of generating between 102 MW & 118 MW, two condensing turbines producing 134 MW, and backpressure steam turbines capable of 65 MW. A size 300FT Spacer-Type Clutch to automatically disconnect condensing turbine when additional steam is needed for Bayer, Dow Chemical Canada, Inc., and NOVA Chemicals, Ltd. located nearby.

Mr. Grant Berg, TransAlta, inspecting Size 300FT Spacer-Type Clutch shown during installation at TransAlta's Sarnia Regional Cogen Facility



Thank You

Clutch Company, Inc.