THYCON

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Shore to Ship Power Technology Appraisal

Introduction

This paper discusses the relative merits of adopting a Centralised versus De-Centralised Distribution system for providing 60Hz Shore to Ship Power utilizing Thycon MPX or HPX Static Frequency Converter Technology.

We also introduce the concept of the Thycon Power Pod for streamlining site installation while providing flexibility in installation and transportability.

Each provides various advantages depending on site requirements.

Static Flywheel

All Thycon SFC equipment utilises our proprietary Static Flywheel technology. This unique approach provides Thycon with the capability to provide power to a wide range of loads by providing dynamic reactive support directly at the SFC output.

The Static Flywheel provides a reservoir of short term energy to meet sudden load demands. The size of the static flywheel can be easily upgraded and thereby improve the ability of the SFC to cope with dynamic changing loads.

The use of thyristors (as opposed to IGBTs and other similar devices), allows the SFC protection to be achieved with resettable circuit breakers as opposed in multiple individual fast HRC fuses. This is due to the significantly higher fault current level of the thyristor as opposed to other power devices.

All these factors combine to provide a machine that is static, has an industry low component count, is robust, largely maintenance free, efficient and easily upgradeable. As with all Thycon industrial equipment it is designed for a 25 year plus service life and as a locally manufactured product you have the confidence that technical support and parts backup is all Australian based.

440V, 960V & 11kV Distribution

Distribution Levels are grouped into four main categories:

- Extra Low Voltage (ELV) 0 to 50VAC
- Low Voltage (LV) 50V to 1000VAC
- Medium Voltage (MV) 1000VAC to 38kV
- High Voltage (HV) 38kV and Greater

Power distribution across the wharf is achieved at a variety of voltage levels, the higher the voltage the smaller the upfront cabling cost, however for voltage levels greater than 1000VAC, tighter restrictions are mandated for risk management and this may lead to greater upfront capital costs and higher ongoing operational costs, depending on the size and scale of the site.

Thycon has implemented 60Hz power distribution at a variety of voltage levels.

440V – this is typically used for short distributions ideally to single cope locations. In this case, voltage drop and voltage imbalance between cope points can be an issue due to the relatively high currents required and the potential for different run lengths. This effect can be negated by increasing the cable sizing, however this contributes a higher cost to the installation. The major advantage of this approach is the elimination of a step down transformer at the ship.

960V – this is a popular alternative for many sites as it realises significant cable cost and switchboard reductions, and avoids the cost and risk management controls that operating in the MV region require. 960V operation represents an increase in power density of more than 200% in comparison to standard 400/415/440V reticulation. Step Down transformers are required at the load to convert 960V to 440V for Ship's use. For replacement or upgrade requirements, most cable used in LV situations is rated to 0.6/1kV in compliance with AS/NZS 5000.1 or IEC 60502.1 and is therefore suitable for operation at 960V.

6.6kV/11kV/22kV – for very large installations, MV reticulation may be used. The MV may be transmitted at either 50Hz or 60Hz. This voltage scheme is ideal for very large installations, as it can significantly reduce the upfront capital cost of cabling.

For 960V and MV reticulation, standard MEN protection systems may be installed as only the step down transformer output needs to float.

HPX and MPX Series Static Frequency Converters

Thycon Static Frequency Converter equipment is available in two classes to suit the various power requirements and operating conditions of site:

MPX – For 20kVA to 1600kVA Single Unit Capacity
HPX – For 2000kVA to 5000kVA Single Unit Capacity

The MPX series equipment operates on 400V to 440V power, while the HPX takes advantage of the higher operating efficiencies achievable at 960V.

Both series of equipment operate within the Low Voltage range and therefore avoid the complications and risks inherent in adopting a MV solution.

Both systems have the necessary over load and transient capability required to cope with a wide range of loads, power factors and current surges and may operate in parallel to meet greater capacity or redundancy requirements.

Greater Operating Efficiency – HPX SFC Series
For high power applications (>1600kVA), Thycon's HPX Series of SFC units operate on a 960V philosophy. Operating at this power provides many cost and efficiency advantages which are explained below.

SFC Operation
A 960V SFC will provide higher efficiency performance, as current draw reduces for a given power output. This is due to both power conductor and semi-conductor component losses diminishing.

On State Volt Drop Across Semi-Conductor Components
On average, a thyristor exhibits an on-state voltage drop of 1.4V. The power loss across the device is the product of the conduction current and on state voltage drop. By reducing the current the thyristor losses are directly reduced.

Other power electronic components, such as IGBT typically exhibit a significantly higher on state voltage drop (around 2.8V), and therefore worse efficiencies exist in their implementation.

I^2R Losses Across Power Conductors
Throughout the SFC power circuit, all conducting elements have impedance. Any current flowing will therefore lose energy in accordance with the formula: current^2 x impedance. As such doubling the voltage, halves the current which results in a 75% transmission efficiency benefit.

SFC Output Transformer
The SFC output transformer has two major sources of loss:

- Core Losses
- Winding Losses

In general, these losses are a function of the transformer construction, and are relatively constant for a given transformer kVA rating.

Cooling Losses
For every dollar of energy saved, cooling costs are reduced, effectively doubling the overall efficiency saving. This efficiency saving occurs not only at the SFC but throughout the entire reticulation.

Thycon SFC systems are built for operation at high ambient temperatures (up to 40°C) while our major magnetic components are rated for operation at up to (150 °C). This ensures cooling costs can be focused only where required.

Thycon Power Pods

Thycon offers equipment in self contained environmental enclosures complete with the necessary HPX or MPX SFC unit, switchboard, air conditioning, input/output transformers, controls and monitoring hardware.

The Thycon Power Pods minimise the required site works and infrastructure by providing the conversion equipment within a fully pre-fabricated and tested housing.

Thycon Power Pods provide customers with many features over traditional fixed rotary installations including:

- High operating efficiency
- High availability, reliability and MTBF figures (100,000 – 1,000,000 hrs)
- Unity input power factor & low input current distortion
- High overload and transient capability
- Reduced audible noise emissions
- Ability to connect capacitors for short term ride-through capability
- Ability to connect batteries for uninterruptible capability
- Ability to parallel multiple units for increased capacity or redundancy

Thycon Power Pods provide customers with many benefits over traditional fixed rotary installations including:

- Reduced carbon emissions
- Reduced ongoing maintenance, remedial and training costs
- Reduced upfront capital costs
- Transportable modules
- Long life
- Australian Made

Each Thycon Power Pod is a self contained unit and includes the following features:

- Connection points for incoming 50Hz power (optional plug/socket arrangement)
- Connection points for outgoing 60Hz power (optional plug/socket arrangement)
- Integrated input / output switchboard
- Integrated sealed air cooling systems
- Start/Stop/EPO controls
- Low level voltage free relay contacts
- Parallel communication port for parallel connection of additional Pods
- HMI including 200 event diagnostic alarm log, input/output variables, LED mimic display, audible & visual alarm notification
- Internal lighting and general power
- Housing - Portable marine grade shipping Container or fixed purpose built Enclosure

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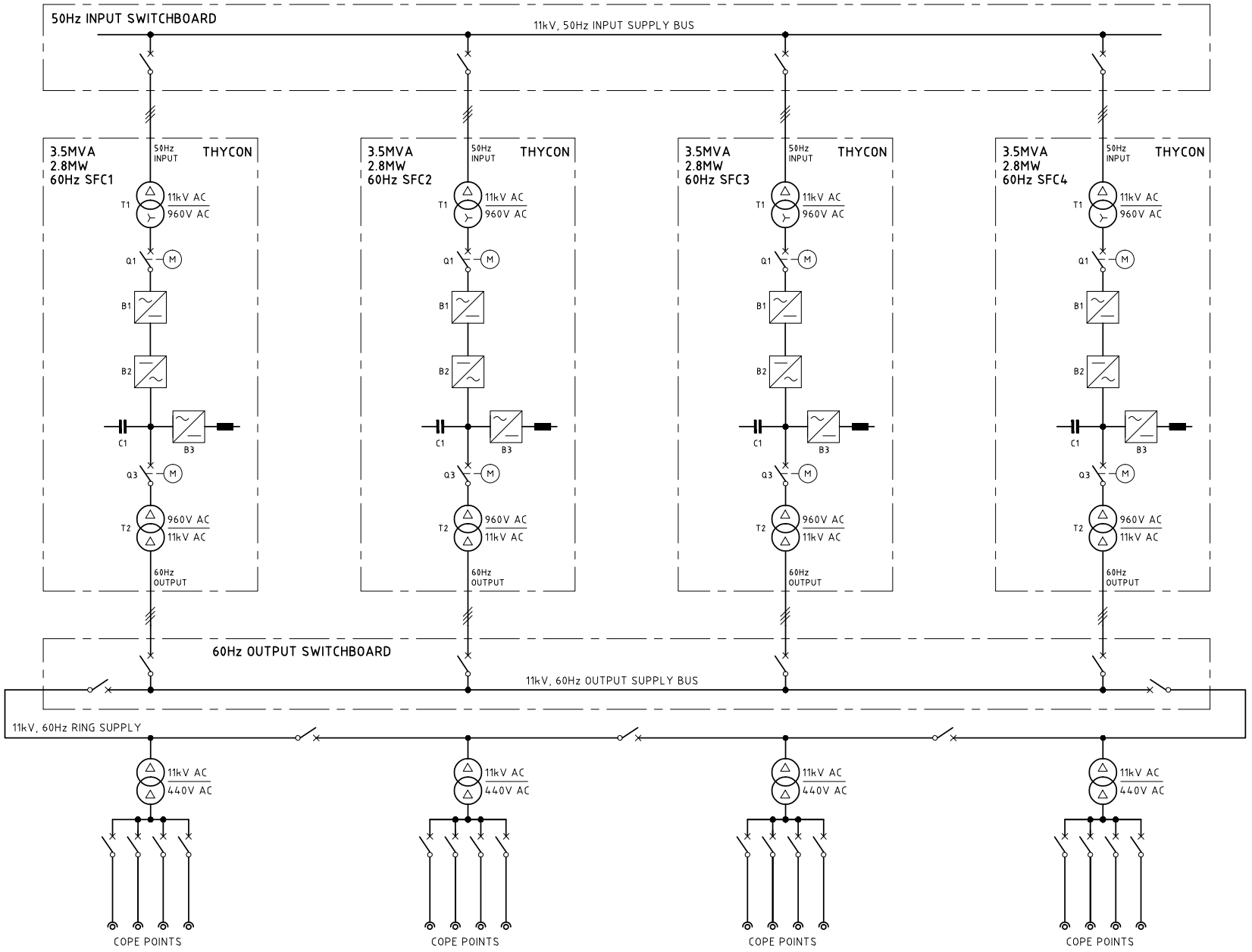


NOTES:

1. DO NOT SCALE DRAWING.
2. DETAILS ARE SUBJECT TO CHANGE WITHOUT NOTICE.

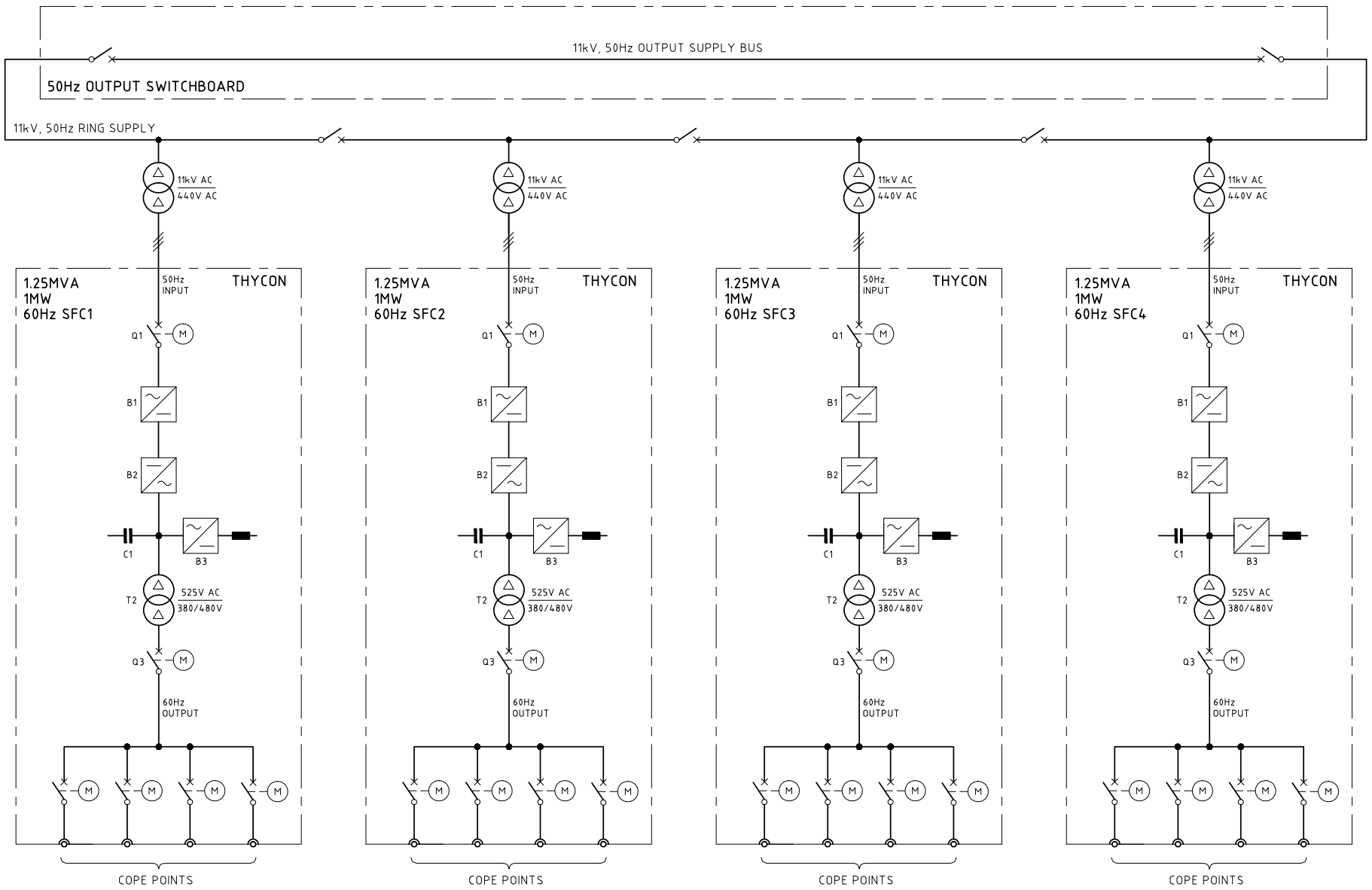
PRELIMINARY

REV	DESCRIPTION	DATE	DRWN	CHK'D

Quality Endorsed Company ISO 9001 QEC 5742

DRWN G.L 25/5/2011	THYCON	CONCEPT 1 – CENTRALISED POWER DISTRIBUTION
CHK'D		4x 3.5MVA/2.8MW 60Hz STATIC FREQUENCY CONVERTER (SFC)
APP'D	SCALE	PROPOSED SINGLE LINE DIAGRAM
PART No:	DISK:	JOB No: ENQUIRY / DWG No: L01550 / SHT OF

CONFIDENTIAL INFORMATION



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PRELIMINARY

REV	DESCRIPTION	DATE	DRWN	CHK'D

Quality Endorsed Company ISO 9001 QEC 5742

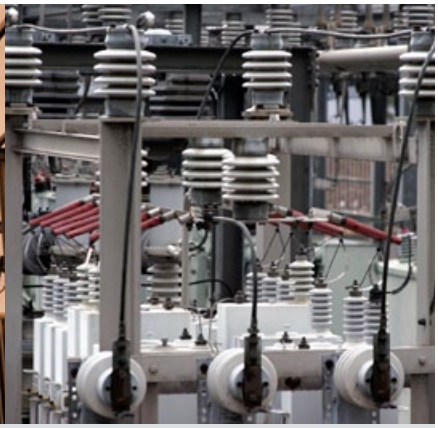
DRWN G.L 25/5/2011
CHK'D
APP'D
PART No:

THYCON

SCALE
DISK:

CONCEPT 2 – DECENTRALISED POWER DISTRIBUTION
4x 1.25MVA/1MW 60Hz STATIC FREQUENCY CONVERTER (SFC)
PROPOSED SINGLE LINE DIAGRAM

JOB No: ENQUIRY | DWG No: L01551 | SHT OF



Options:

- Paralleling control box
- High level communication standards
  - SNMP
  - HTML
  - SMTP (Email)
- Master control box for automatically start/stopping individual SFC units based on load demands
- External marshalling box for connection/ disconnection of alarms
- 50Hz output power for local use by other applications

The Thycon Power Pod is a 100% Australian designed and manufactured product with the head office/manufacturing facility located in Melbourne and service/sales located in Sydney, Canberra, Brisbane, Perth, Adelaide & Darwin.

Case Study 1:
Centralised Power Distribution
11KV Reticulation – 14MVA System

Refer to Drawing – L01550 – Centralised Power Distribution Single Line Diagram

Thycon proposes the supply of four (4) 3.5MVA/2.8MW HPX SFC Systems connected in parallel to provide 14MVA/11.2MW of total capacity or 10.5MVA/8.4MW redundant capacity.

Each 3.5MVA HPX SFC is housed in a Thycon Power Pod and supplied with dedicated Input & Output Transformers for conversion between 11kV and 960V.

Further 3.5MVA HPX SFC Systems can be added as required for increased capacity or redundancy.

System Advantages, Features and Benefits
The Thycon Power Pods (TPPs) eliminate the need for special rooms to be constructed and allows onsite works to be minimised.

A 960V operating voltage has been nominated to maximise power densities and overall equipment efficiency while gaining the cost advantages inherent in using standard LV power components and avoiding the design & safety constraints inherent in adopting a completely MV solution.

An optional Power Efficiency Control System is available for overall co-ordination of the TPP operation to ensure minimum carbon emissions and maximum operating efficiency for the site 60Hz supply. The PECS monitors the load requirements and automatically starts or stops TPP modules as required, therefore maintaining maximised efficiency and minimised operational electricity costs. Millions of dollars in electricity cost savings can be made over the lifetime of the equipment depending on site loading conditions.

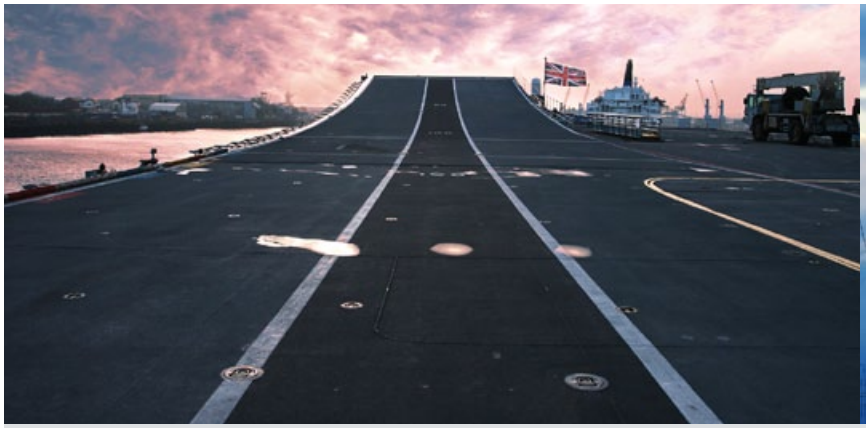
A Capacitor Bank or Battery Bank may be added at any time to each TPP to provide short term ride-through or uninterruptible capability respectively if required.

High level monitoring of the system status, operating variables and event history may be achieved using standard industry building monitoring systems. Thycon can also provide a HTML web page front end to enable interrogation of the TPP status/event history and operating variables by remote users.

Equivalently sized TPPs simplify maintenance, training and safety, therefore minimising the risk of error and storage of spare parts due to the commonality between units.

An individual TPP can be removed at any time for maintenance works or additional TPPs can be installed to provide increased capacity or redundancy as required.

Further, Thycon Power Pods can be relocated to other sites if load requirements change.



Case Study 2:
De-Centralised Power Distribution
440V Reticulation – 5MVA System

Refer to Drawing – L01551 – De-Centralised Power Distribution Single Line Diagram

Thycon proposes the supply of four (4) 1.25MVA/1MW MPX SFC Systems connected at the output of each Cope Point Step Down Transformer to provide 5MVA/4MW of total capacity.

In this scenario, portable Thycon Power Pods complete with 1250kVA MPX SFC units are utilised. Each Thycon Power Pod is provided with connection points for the incoming 440V/50Hz power and cope sockets for connection to the Ship.

System Advantages, Features and Benefits

As ships arrive on the dock, the Thycon Power Pods (TPP) can be relocated to suit the ship requirements. Each TPP is rated to take advantage of the capacity available in each 11kV/440V step down transformer. Each TPP operates independently providing power to the ship(s) at each fixed location. It is not envisaged to have any common synchronizing control between the units, however this can be provided if required.

A Capacitor Bank or Battery Bank may be added at any time to each TPP to provide short term ride-through or uninterruptible capability respectively if required.

High level monitoring of the system status, operating variables and event history may be achieved using standard industry building monitoring systems. Thycon can also provide a HTML web page front end to enable interrogation of the TPP status/event history and operating variables by remote users.

Equivalently sized TPPs simplify maintenance, training and safety, therefore minimising the risk of error and storage of spare parts due to the commonality between units.

An individual TPP can be removed at any time for maintenance works or additional TPPs can be installed to provide increased capacity or redundancy as required.

Further, Thycon Power Pods can be relocated to other sites if load requirements change.

Summary Comparison

The summary comparison of Centralised vs De-Centralised Power Distribution provides various points for consideration:

Redundancy

At a system level, Centralised Power Distribution achieves simpler upgrade-ability as additional TPPs can simply be installed to increase site redundancy at minimal incremental cost. A De-Centralised system requires additional modules at each Cope Point to achieve overall redundancy potentially leading to higher overall cost.

Capacity Increase

De-Centralised Power Distribution achieves simpler upgrade-ability as additional TPPs and infrastructure including supply, reticulation, etc can be installed to meet the individual requirements at minimal incremental cost. A Centralised system requires supply and reticulation to be sized correctly from the start.

Efficiency Cost Savings

Centralised Power Distribution combined with a Power Efficiency Control System allows close matching of SFC Power to Load requirements.

Closely matched Supply to Load functionality allows the SFC system to operate at maximised efficiency leading to maximised cost savings.

De-Centralised system also operates at high efficiency as only those Cope Points requiring power need be utilised.

Ease of Maintenance, Training and Spare Parts

Modular design of both Centralised and De-Centralised Power Distribution allows the same components and philosophy to be utilised across the installation achieving real Maintenance, Training and Spare Part savings. Operation within the Low Voltage range of <1000V at either 440V or 960V avoids the complications, risks and increased costs associated with MV requirements.

Transportability

Thycon Power Pods minimise the required site works and infrastructure by providing the conversion equipment within a fully pre-fabricated and tested housing. The TPPs can easily be relocated to other locations or sites if load requirements change.

I^2R compensation

Run lengths of cable between source of power and connection points must be addressed carefully across all installations. Both Centralised and De-Centralised Power Distribution systems offer advantages depending on the site requirements.

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