

REVISION HISTORY

Revision	Author	Date
2	Erick Wipf	22 May 2020

SUMMARY

The Power + ORC is an organic Rankine Cycle (ORC) electrical generating system designed to convert low grade heat into electrical energy to be fed into the power grid. The major electrical components of the Power + ORC include the induction generator, power factor correction (PFC) capacitors, working fluid feed pump and motor, pump control variable frequency drive (VFD), cooling pump, liquid loop radiator, 120 volt control transformer, 24 VDC power supply, process logic controller (PLC), a human machine interface (HMI/touch screen), electrical metering equipment, various fuses and circuit breakers, a master control relay (MCR), and miscellaneous transducers, relays, and input output I/O devices, such as dry (unpowered) relay contacts for controlling customer supplied auxiliary equipment.

The system controls occupy two NEMA 4 rated panels, one for power components, operating at 380-500 VAC, and the other for controls, at voltages of 120 VAC or less.

ELECTRICAL PANEL SAFETY

The Power Plus ORC's electrical panels were designed with operator and technician safety in mind. By separating the higher voltage power components such as the VFD, PFC, electrical metering, and contactors from the lower voltage PLC, I/O devices, and relays, service personnel safety is maximized.

Fusing and circuit breakers in both panels are designed to limit fault currents per National Electrical Code (NEC) requirements. Arc flash hazard is mitigated below these fuses to limit incident energy to Category 0 PPE requirements, however, the power cabinet rating will be determined by upstream protective device ratings. Short Circuit Current Rating (note: this is not the fault contribution of the machine) will be engineered to be 50 kA or greater, providing a margin of safety in the event of an electrical fault.

Grounding systems are tested for low impedance per EN 60204-1:2006. In addition to the power cabinet ground bus and lug, the machine frame has approved auxiliary grounding locations at each corner. Additional frame grounding points are provided to facilitate compliance with local electrical codes.

In both the Power and Control panels, all components are insulated and meet Finger Safe requirements per IEC IP20, and the overall panel design is compliant with UL 508A. Insulation resistance testing, and withstand voltage (HiPot) testing are performed per EN 60204-1:2006. The Power panel includes a door-interlocked disconnect switch that also serves as an energy control (lock-out) point for the machine. Pictorial multi-language warning labels for all hazard types are attached throughout.

CONNECTION OF GENERATOR TO UTILITY GRID:

The ElectraTherm Power + ORC uses an asynchronous induction generator to connect to the electrical grid. The Generator is brought up to near synchronous speed mechanically via the expander, and is connected to the grid with a minimum of inrush current. The synchronous speeds are: 3000 RPM for 50 Hz, or 3600 RPM for 60 Hz. An asynchronous induction generator is electro-mechanically similar to an induction motor that is driven slightly above synchronous speed. The maximum possible in-rush current for the generator during start up, is the Locked Rotor Amps (LRA). This inrush current occurs at grid connection typically lasts for less than 100 milliseconds. The in-rush current that flows is to magnetize the generator; however, with the generator already being near synchronous speed, no large acceleration current is required at grid connection. Specific generator information is available in the manufacturer's generator datasheet, available from ElectraTherm. For grid connection characterization, please reference attached drawings.

MINIMUM SIZE OF UTILITY GRID REQUIRED FOR CONNECTION:

Since the Power + ORC requires an active grid to provide the voltage and frequency regulation for the generator, there are limits on how small of a grid the Power + ORC can connect to. The Power + ORC generator requires a synchronous generating capacity and associated loads of at least 6x the induction generator capacity. Smaller grids may be evaluated for suitability on a case-by-case basis.

VOLTAGE OF UTILITY GRID:

The induction generator supplied with the Power + ORC is rated for 400V/50Hz/3 phase or 480V/60Hz/3 phase. Different voltage connections to the Power + ORC can be achieved through the use of external transformers.

VOLTAGE AND FREQUENCY REGULATION OF THE GENERATOR:

Voltage regulation and frequency regulation are provided from the existing connection to the power grid. Because induction(asynchronous) generators are not self-excited and have no magnetization or terminal voltage prior to grid connection, the actual voltage and frequency of the grid will determine the frequency and voltage level that the induction generator produces.

INTERNAL POWER + ORC POWER FACTOR CORRECTION:

The Power + ORC comes standard with two stages of power factor correction utilizing power factor correction capacitors. The capacitors used are specific based on the grid voltage and frequency. The ORC control system controls the application of the power factor correction capacitors to maintain power factor >0.95.

The power factor correction capacitor(s) are connected via contactor to the grid inside the Power + ORC power panel. During shut down, the power factor correction caps are disconnected from the system supply to not influence the induction generator during a shutdown condition.

THE POWER+ ORC CANNOT OPERATE IN ISLAND MODE:

By inherent nature of the induction generator design, and internal controls built into the Power + ORC, the generator is unable to "island" for any extended period of time. After a grid disconnection, the generator contactor opens, and the power factor correction capacitor contactors are opened, disconnecting the PFC caps from the grid as well. Removing the reactive power provided by the power factor correction caps, as well as isolating the generator terminals from the grid and capacitors prevents the induction generator from islanding.

BASIC GENERATOR SPECIFICATIONS (SEE DATASHEETS FOR FURTHER DETAIL)

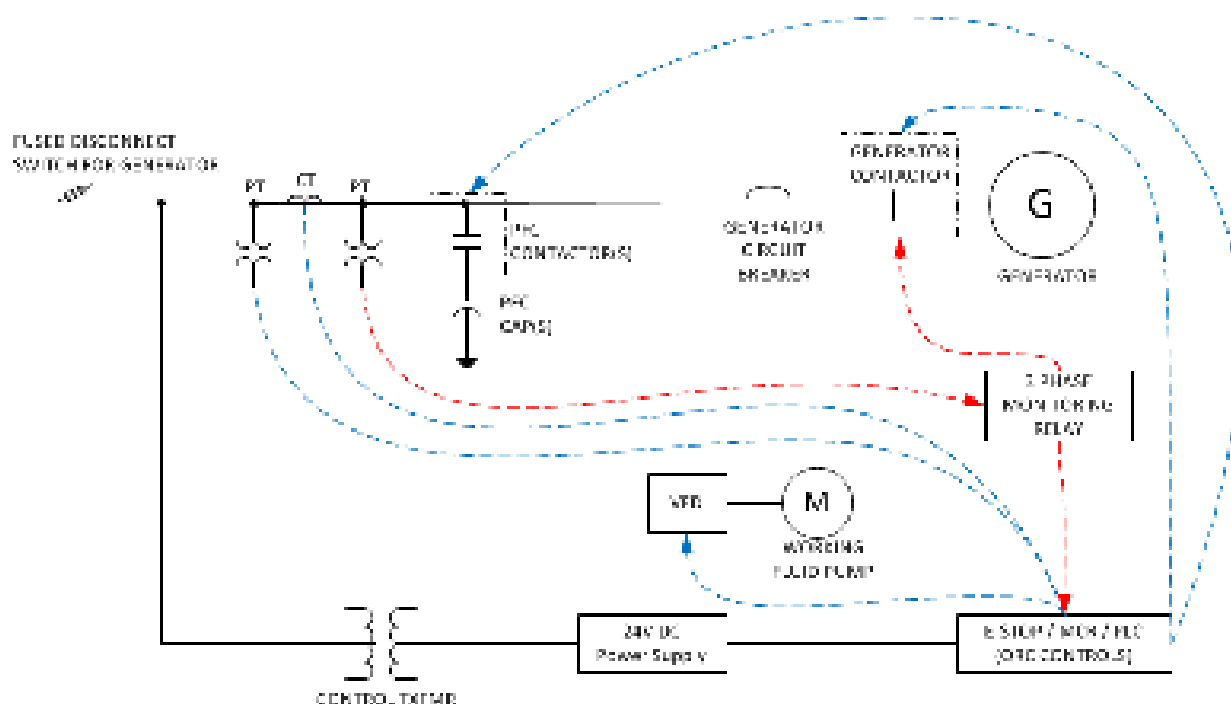
Basic Induction Generator specifications for P+ 4400B/6500B				
Model	P+4400B/75kWe		P+6500B/125kWe	
Grid Frequency	50Hz	60Hz	50Hz	60Hz
Rated Output	75kWe	75kWe	125kWe	125kWe
Phase	3 phase	3 phase	3 phase	3 phase
Voltage	380-420VAC	460-500VAC	380-420VAC	460-500VAC
Connection Type	3 wire delta	3 wire delta	3 wire delta	3 wire delta
Full Load RPM	3027 RPM	3622 RPM	3027 RPM	3622 RPM
In-rush current	<700A	<700A	<1400A	<1400A
In-rush current duration	<100ms	<100ms	<100ms	<100ms

GRID INTERCONNECTION CONTROLS:

The Power + ORC 's PLC and included secondary three phase monitoring relay monitor the following conditions during operation, and will shut down the Power + ORC and disconnect it from the grid in the event that any of the faults below occur. Some values are adjustable at the relay, or adjustable via HMI interface to the PLC. Please reference picture below the table for further clarification on how protective signals are used. A single line of the protection circuit is available upon request if needed by the utility

Over voltage	monitored/controlled by relay
Under voltage	monitored/controlled by relay
Over frequency	monitored/controlled by PLC (speed monitoring)
Under frequency	monitored/controlled by PLC (speed monitoring)
Over current	monitored/controlled by PLC
Low kWe production (under current)	monitored/controlled by PLC
Loss of phase	monitored/controlled by relay
Phase current imbalance	monitored/controlled by PLC*
Phase rotation	monitored/controlled by relay and PLC

*Phase current imbalance is monitored via the plc, and the values allowed for a phase imbalance are set by the generator manufacturer's requirements, and are not adjustable.



USE OF EXTERNAL GRID PROTECTION RELAY:

While the Power + ORC inherently has built in grid interconnect controls, if for any reason, the included disconnect controls do not match what the local authority having jurisdiction (utility, inspector, city, state, etc...) requires, a separate Grid Protection relay may be needed.*

Additional protection could take the form of ground fault relays, or remote trip capability. The Power + ORC provides an external input for this purpose. This dedicated and separate E-stop (GPR) input should be used when an externally activated shunt trip relay/breaker is required.

*The external grid protection relay is not provided by ElectraTherm.

MASTER CONTROL RELAY, EMERGENCY STOP, AND SHUTDOWN

In addition to the grid protections above, the machine includes a latching Master Control Relay, normally open generator contactor, and failsafe valves which form an independent emergency stop system. This circuit is interrupted by a variety of internal safety interlocks, and is also available for external safety interlocking, and manual activation via red E-stop button.

Monitored parameters for automated shut down additionally include the following:

Over pressure	---transducer and dedicated switch
Over heating	---monitors in generator, working fluid loop, and enclosure
Over or under speed	---via speed sensing circuitry and PLC
Loss of critical sensor data	---controlled by PLC

POWER + ORC CERTIFICATIONS

CE Compliance:

Pressurized Equipment Directive 97/23/EC

Electromagnetic Compatibility Directive 2004/108/EC

Safety of Machinery Directive 2006/42/EC

Low Voltage Directive 2006/95/EC

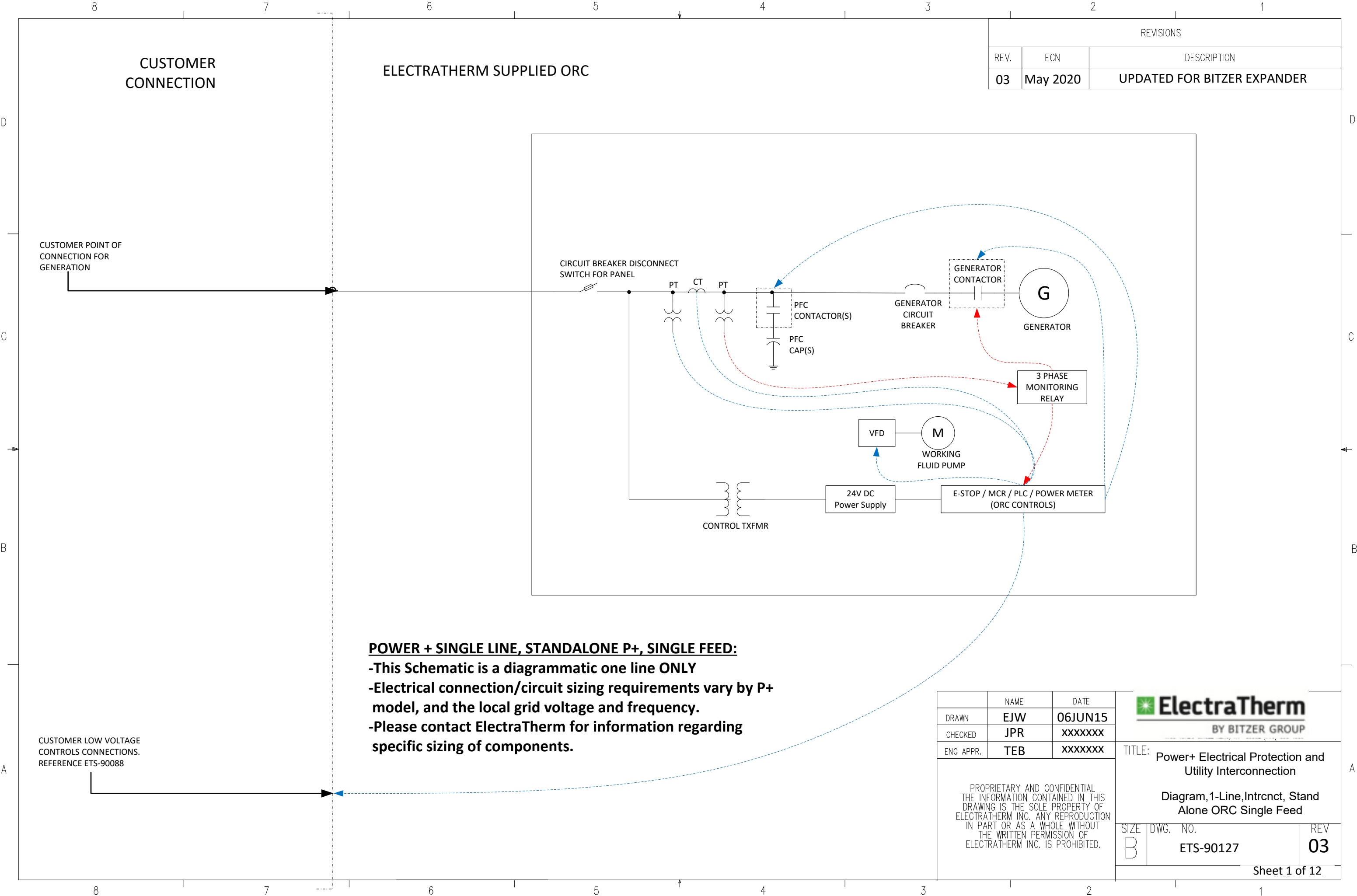
All electrical components meet RoHS requirements

Factory acceptance testing including insulation resistance, HiPot, ground impedance, and full load operation

ADDITIONAL INFORMATION

Reference attached drawings on following pages for further details on:

- 1 line drawing of P+ stand alone ORC with single power feed, and dual power feed configurations
- 1 line drawing of P+ Turnkey ORC system, with single power feed, and dual power feed configurations
- Modes of operation/power flow for single and dual feed configurations.
- RMS current and in rush current profile for series 6000, 480v/60Hz
- RMS current and in rush current profile for series 4400, 480v/60Hz
- P+ protective circuit topology and one line of protective circuit



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POWER + SINGLE LINE, STANDALONE P+, SINGLE FEED:

- This Schematic is a diagrammatic one line ONLY
- Electrical connection/circuit sizing requirements vary by P+ model, and the local grid voltage and frequency.
- Please contact ElectraTherm for information regarding specific sizing of components.

	NAME	DATE
DRAWN	EJW	06JUN15
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ENG APPR.	TEB	xxxxxxx



TITLE: Power+ Electrical Protection and Utility Interconnection
Diagram, 1-Line, Intrcnct, Stand Alone ORC Single Feed

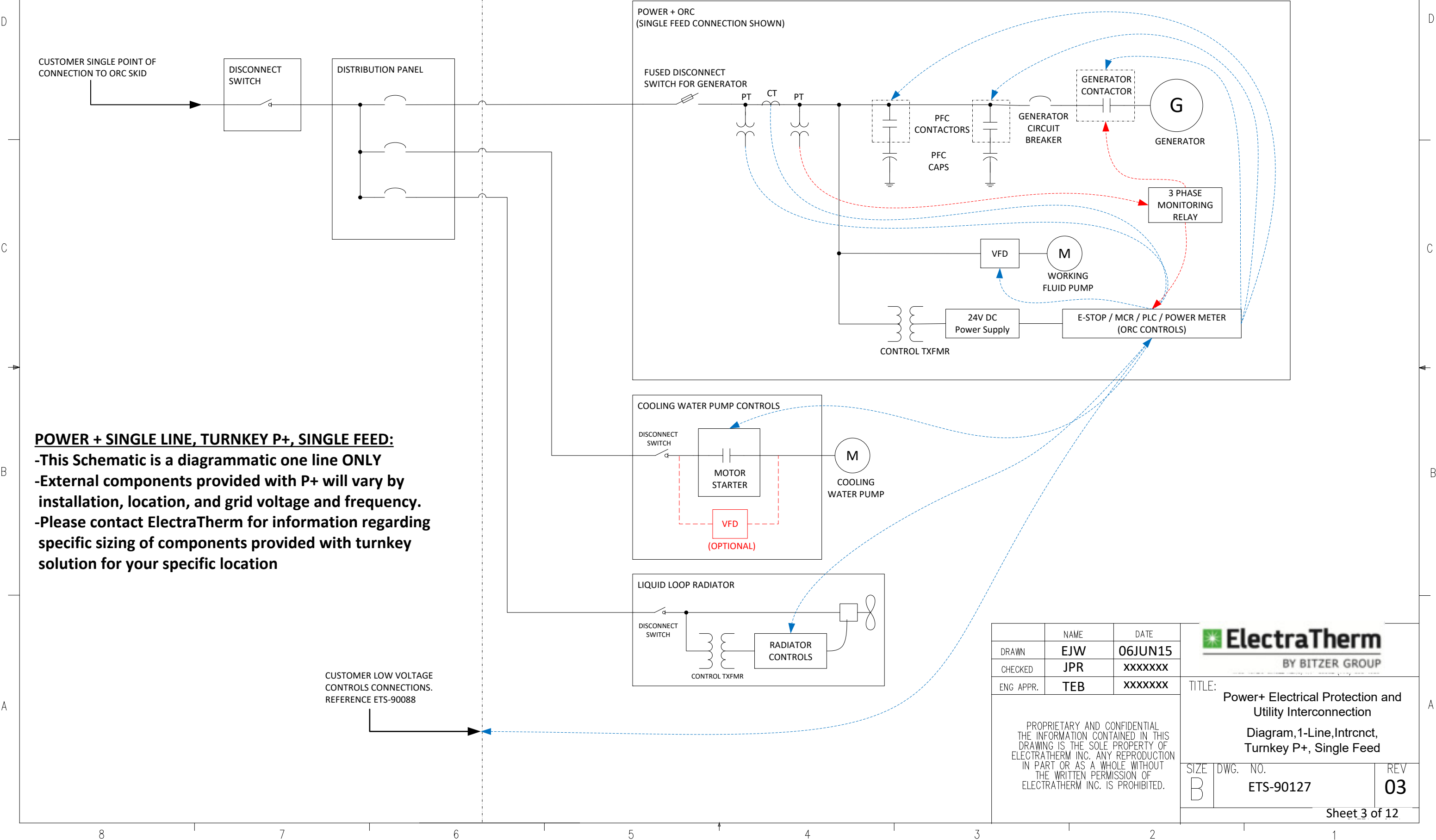
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CUSTOMER CONNECTION

ELECTRATHERM SUPPLIED ORC AND COOLING

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POWER + SINGLE LINE, TURNKEY P+, SINGLE FEED:
-This Schematic is a diagrammatic one line ONLY
-External components provided with P+ will vary by installation, location, and grid voltage and frequency.
-Please contact ElectraTherm for information regarding specific sizing of components provided with turnkey solution for your specific location

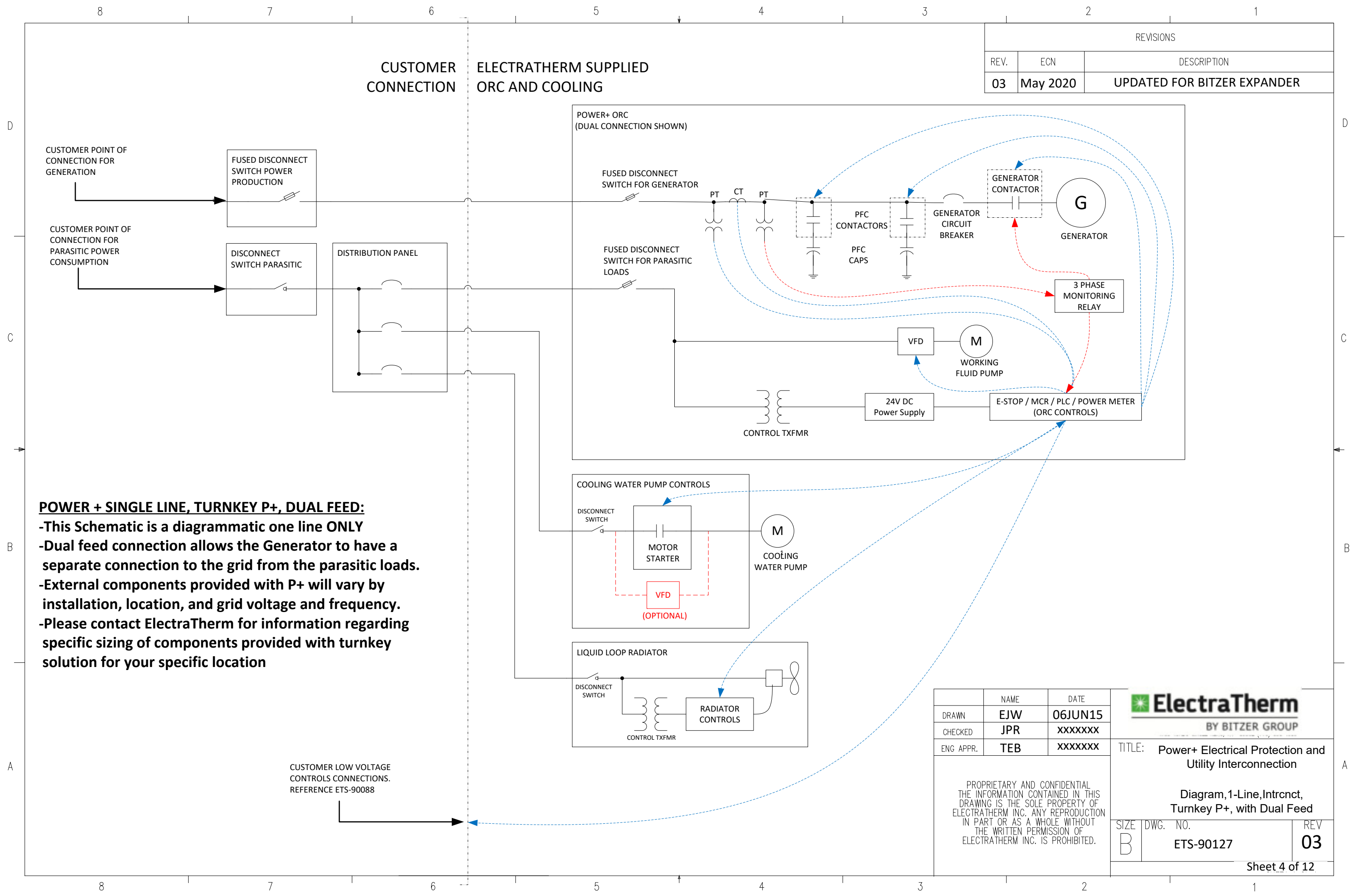
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ENG APPR.	TEB	xxxxxxx

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TITLE:
Power+ Electrical Protection and
Utility Interconnection
Diagram, 1-Line, Intrncnt,
Turnkey P+, Single Feed

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POWER + SINGLE LINE, TURNKEY P+, DUAL FEED:
-This Schematic is a diagrammatic one line ONLY
-Dual feed connection allows the Generator to have a separate connection to the grid from the parasitic loads.
-External components provided with P+ will vary by installation, location, and grid voltage and frequency.
-Please contact ElectraTherm for information regarding specific sizing of components provided with turnkey solution for your specific location

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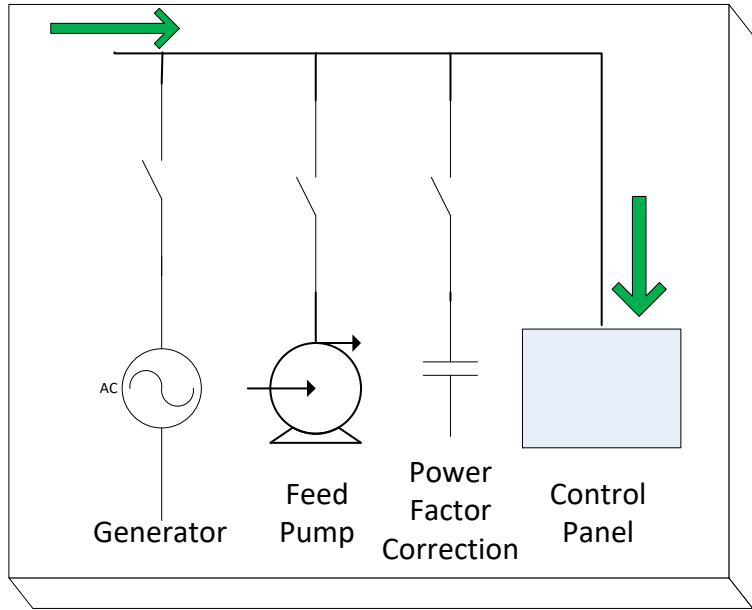


TITLE: Power+ Electrical Protection and
Utility Interconnection

Diagram, 1-Line, Intrcnct,
Turnkey P+, with Dual Feed

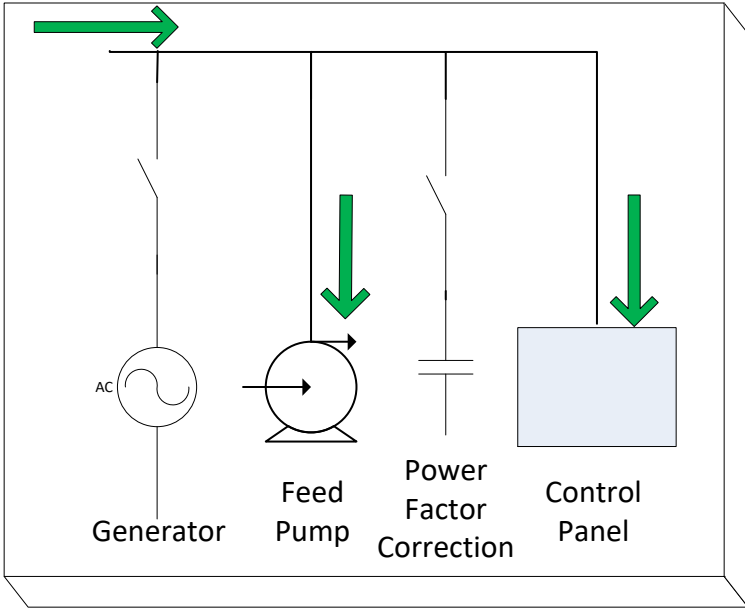
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1. MACHINE IS IDLE OR SHUTDOWN
(Equipment consumes power)



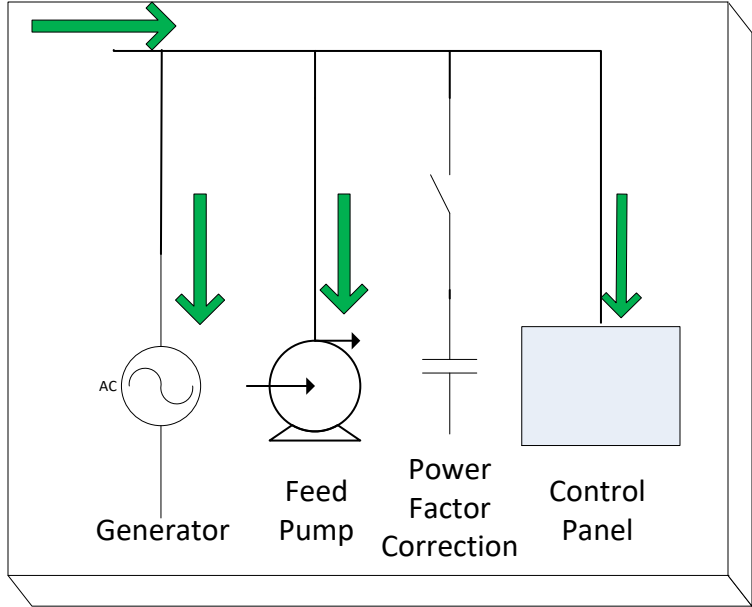
At IDLE, only the control panel consumes power, everything else is disconnected. This can be a steady state condition. This can also be a transient condition waiting for permissives to be met before machine startup is initiated. Power production is NET NEGATIVE, and less than 1kW_e

2. MOMENTARY STATE AT ORC STARTUP
(Equipment consumes power)



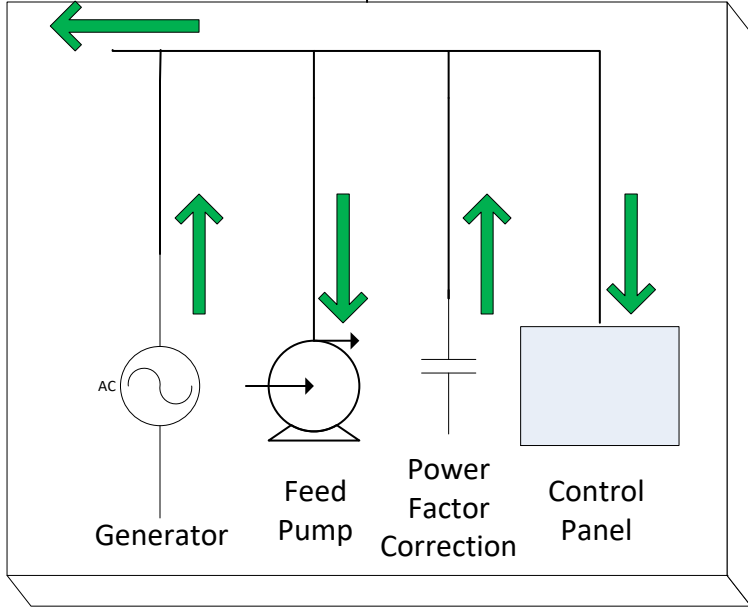
During Startup, the control panel and feed pump consume power, everything else is disconnected. Power Production is NET NEGATIVE, and the ORC is consuming power. This is NOT a steady state condition, and typical start up times are less than 10 seconds, depending on site conditions.

3. MOMENTARY STATE AT GRID CONNECTION
(Equipment consumes power)



At Grid Connect, the control panel consumes power, the feed pump consumes power, and the generator has a short in-rush current immediately at grid connection. Power Production is NET NEGATIVE, and the ORC is consuming power. This is NOT a steady state condition, it is momentary, and peak inrush current duration is <100ms

4. NORMAL OPERATION / POWER PRODUCTION
(Equipment producing power)



During normal operation, the control panel and feed pump consume power, the generator produces power, and the Power factor correction provides KVAR. This is a steady state condition. Power Production is NET POSITIVE, and power is leaving the ORC

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P+ with SINGLE FEED OPTION:

Generator and Capacitors are connected to the grid at a single point. The diagrams depict Green Machine power connection sequence and power/current flow during steady state and transient operating modes.

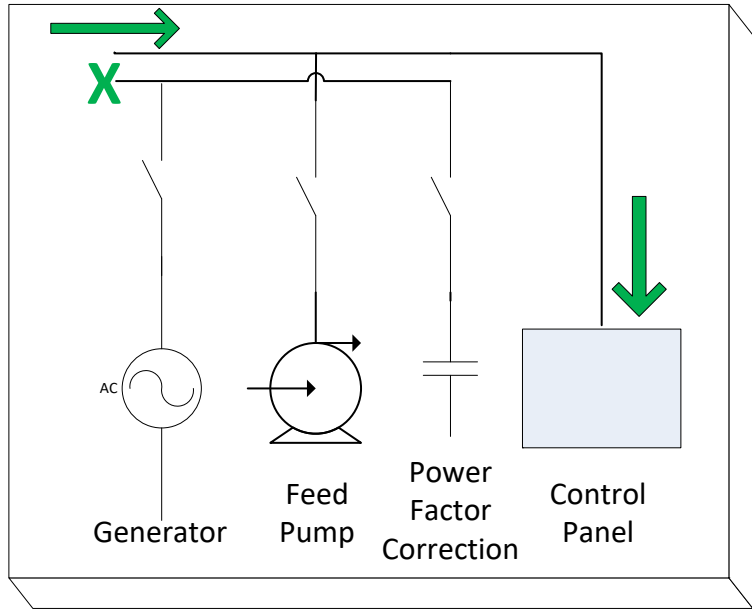
LEGEND

- Direction of current/power flow
- Relay or contactor is "OPEN", This device is disconnected.
- Relay or contactor is "CLOSED", This device is connected.

SEE DETAILED CHARTS ON FOLLOWING PAGES FOR FURTHER DETAIL ON POWER CONSUMPTION AND PRODUCTION PROFILE

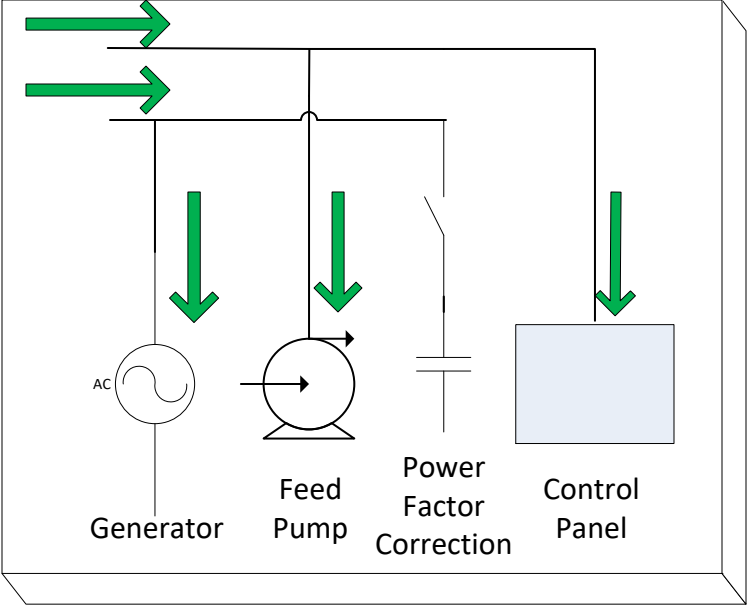
	NAME	DATE	ElectraTherm BY BITZER GROUP	
DRAWN	EJW	06JUN15	TITLE: Power+ Electrical Protection and Utility Interconnection Diagram, 1-Line, Modes of Operation, single feed P+	
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ENG APPR.	TEB	xxxxxxx		
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1. MACHINE IS IDLE OR SHUTDOWN
(Equipment consumes power)



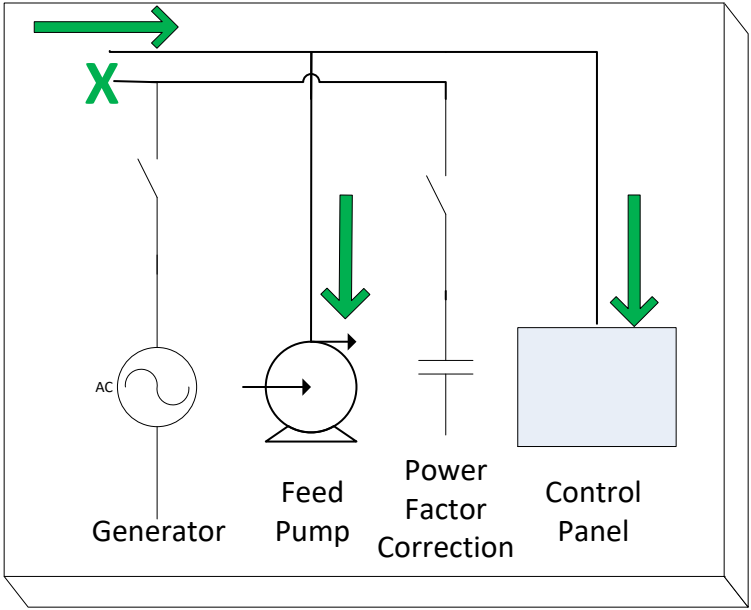
At IDLE, only the control panel consumes power, everything else is disconnected. This can be a steady state condition. This can also be a transient condition waiting for permissives to be met before machine startup is initiated. Power production is NET NEGATIVE, and less than 1kW_e

3. MOMENTARY STATE AT GRID CONNECTION
(Equipment consumes power)



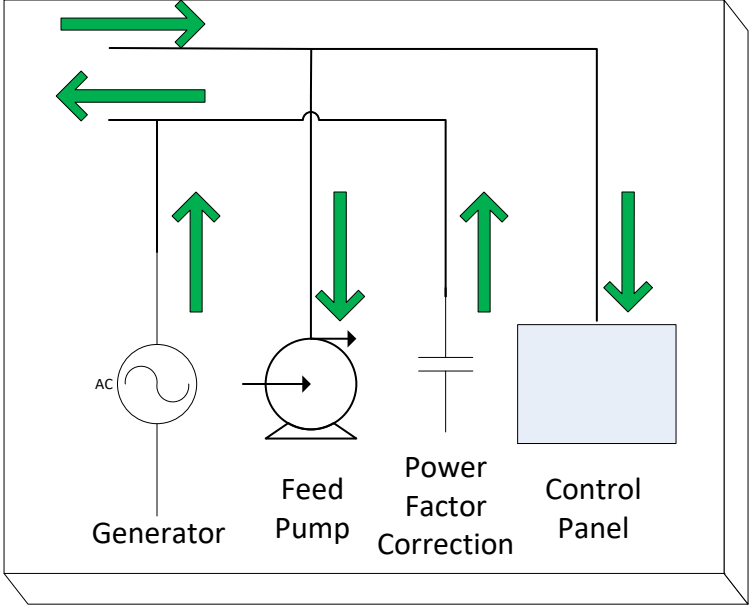
At Grid Connect, the control panel consumes power, the feed pump consumes power, and the generator has a short in-rush current immediately at grid connection. Power Production is NET NEGATIVE, and the ORC is consuming power. This is NOT a steady state condition, it is a momentary, and peak inrush current is <100ms

2. MOMENTARY STATE AT ORC STARTUP
(Equipment consumes power)



During Startup, the control panel and feed pump consume power, everything else is disconnected. Total Effective Power Production is NET NEGATIVE, and the ORC is consuming power. This is NOT a steady state condition, and typical start up times are less than 10 seconds, depending on site conditions.

4. NORMAL OPERATION / POWER PRODUCTION
(Equipment producing power)



During normal operation, the control panel and feed pump consume power, the generator produces power, and the Power factor correction provides KVAR. This is a steady state condition. Total Effective Power Production is NET POSITIVE.

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P+ with DUAL FEED OPTION:

Generator and Capacitors are connected to the grid separately from the rest of the ORC components. The diagrams depict Green Machine power connection sequence and power/current flow during steady state and transient operating modes.

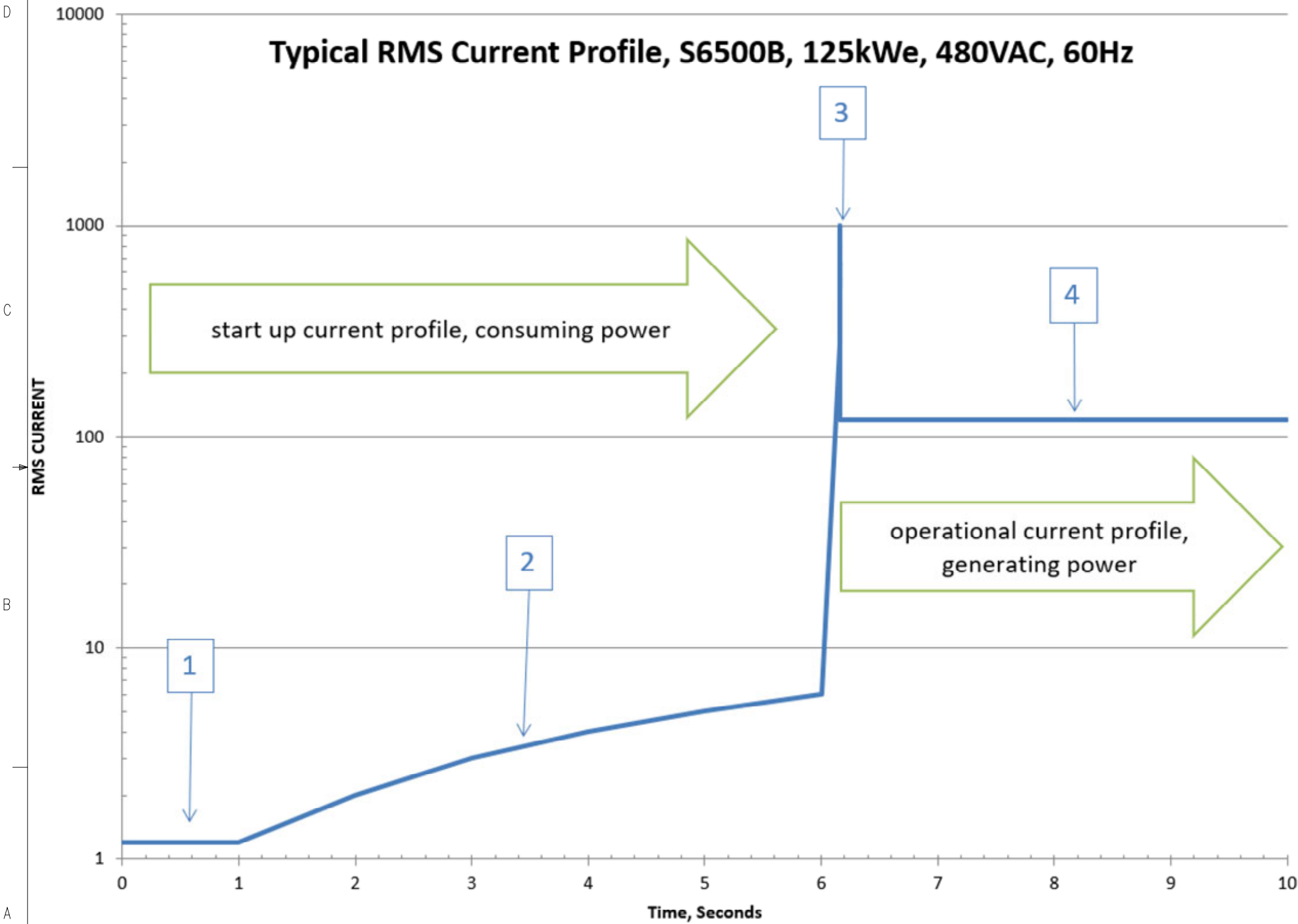
LEGEND

- Direction of current/power flow
- Relay or contactor is "OPEN", This device is disconnected.
- Relay or contactor is "CLOSED", This device is connected.

SEE DETAILED CHARTS ON FOLLOWING PAGES FOR FURTHER DETAIL ON POWER CONSUMPTION AND PRODUCTION PROFILE

	NAME	DATE		
DRAWN	EJW	06JUN15	TITLE: Power+ Electrical Protection and Utility Interconnection Diagram, 1-Line, Modes of Operation, dual feed P+	
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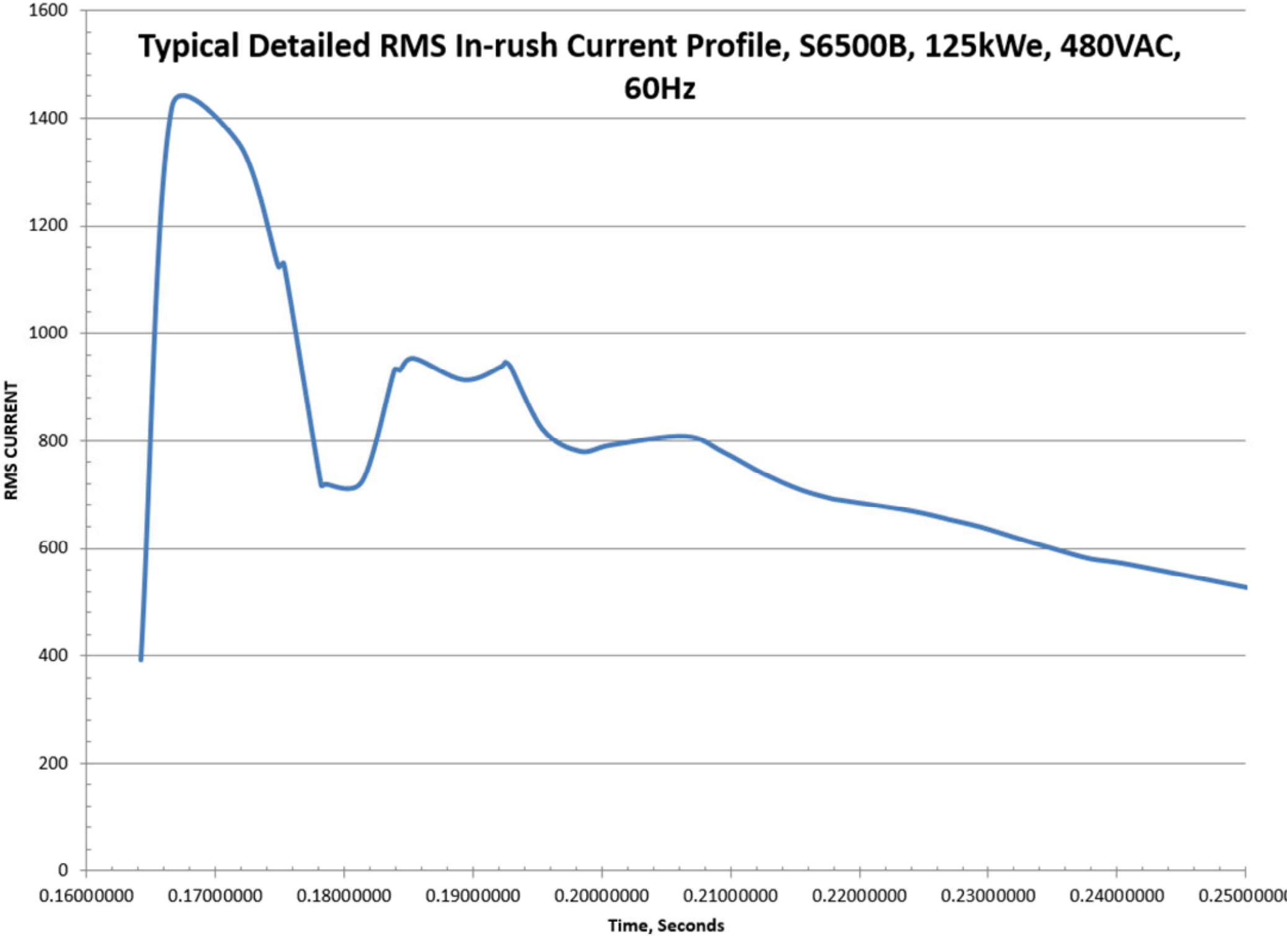
PLEASE NOTE

Values are based on 480VAC, with a line frequency of 60Hz.

Actual values will vary based on site voltage and frequency, as well as thermodynamic conditions presented to the ORC

	NAME	DATE	 ElectraTherm BY BITZER GROUP		
DRAWN	EJW	06JUN15	TITLE: Power+ Electrical Protection and Utility Interconnection S6500B startup operation profile, single feed P+		
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ENG APPR.	TEB	xxxxxxx			
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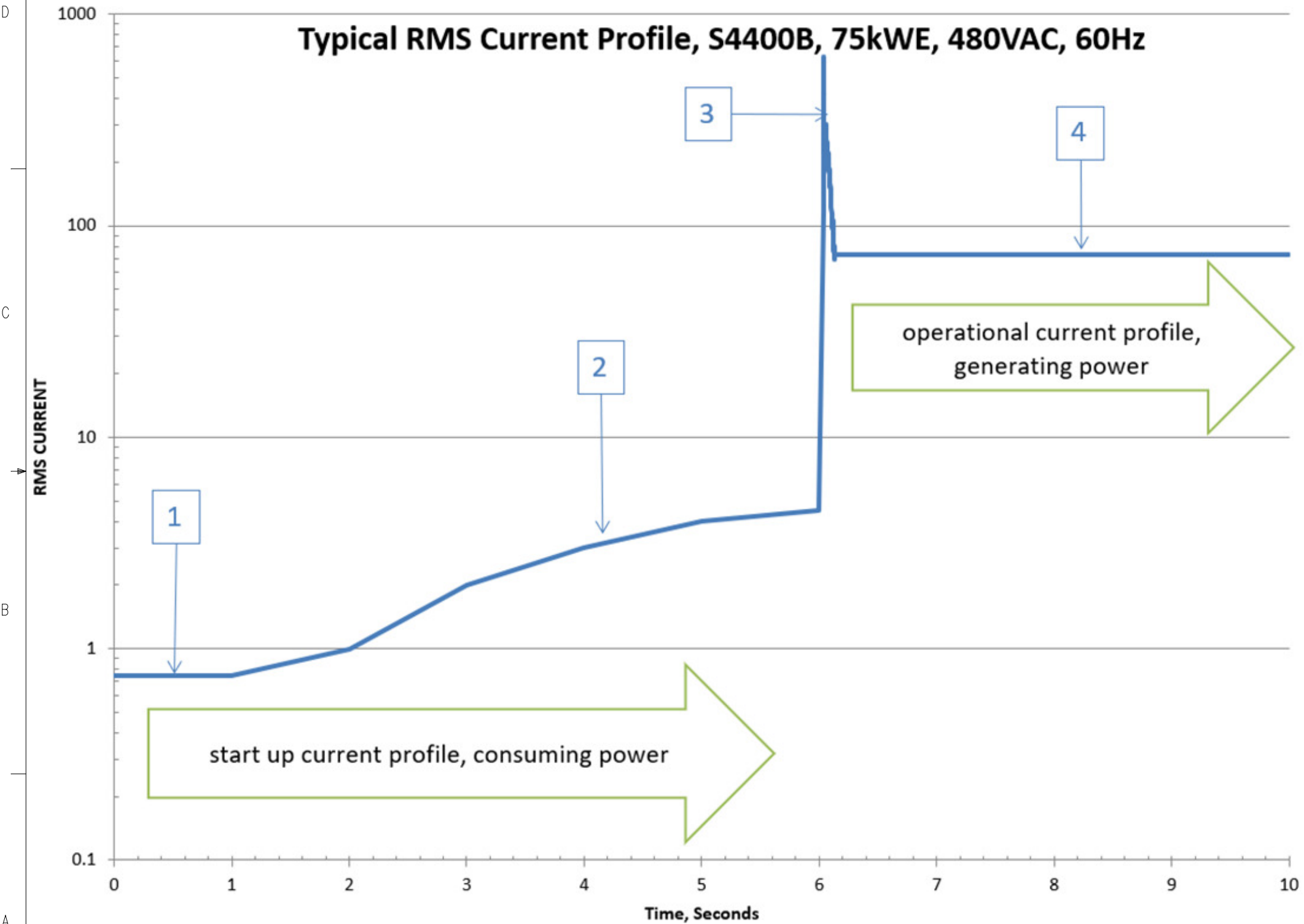
PLEASE NOTE

Values are based on 480VAC, with a line frequency of 60Hz.

Curves will vary based on site voltage and frequency.

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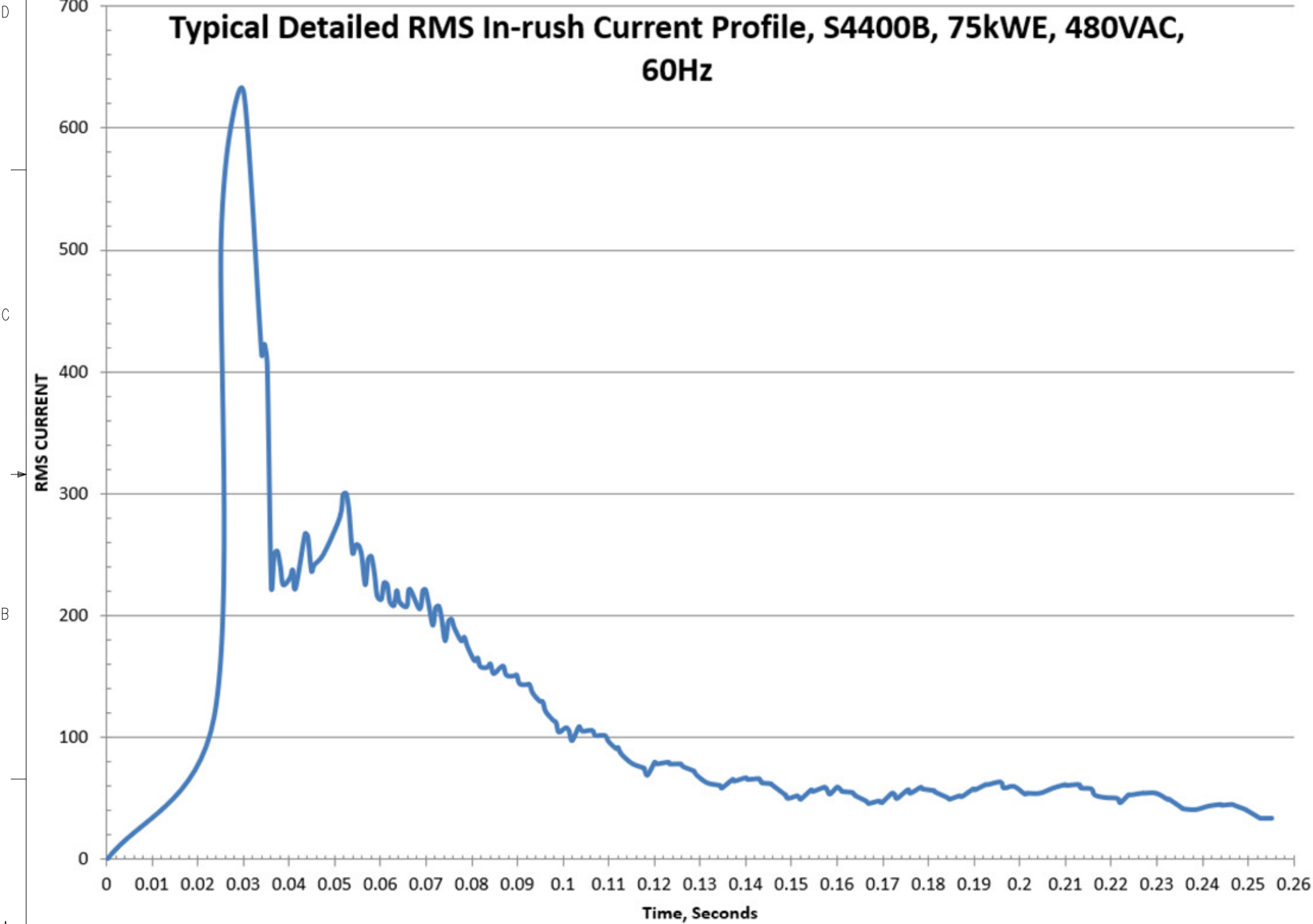
PLEASE NOTE

Values are based on 480VAC, with a line frequency of 60Hz.

Actual values will vary based on site voltage and frequency, as well as thermodynamic conditions presented to the ORC

	NAME	DATE	 ElectraTherm BY BITZER GROUP		
DRAWN	EJW	06JUN15	TITLE: Power+ Electrical Protection and Utility Interconnection S4400B startup operation profile, single feed P+, 75kWe		
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PLEASE NOTE

Values are based on 480VAC, with a line frequency of 60Hz.

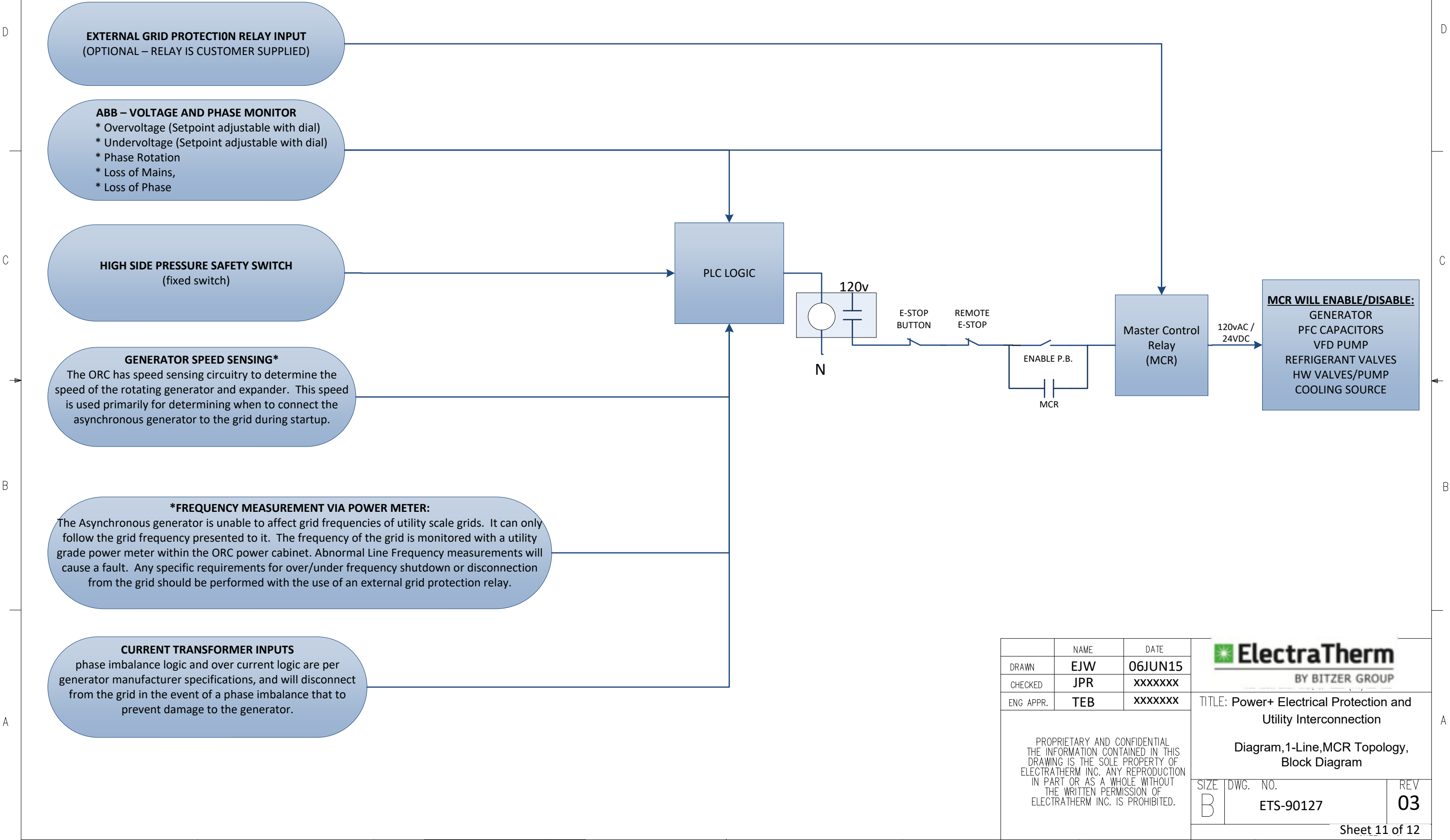
Curves will vary based on site voltage and frequency.

	NAME	DATE			
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MCR / Master Control Relay
MACHINE PROTECTION MCR CIRCUIT DIAGRAMMATIC TOPOLOGY.

--Block Diagram only, for physical implementation, reference complete electrical drawings.

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TITLE: Power+ Electrical Protection and
Utility Interconnection

Diagram, 1-Line, MCR Topology,
Block Diagram

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