PROFESSIONAL DEVELOPMENT
SEMINAR SERIES

GPS-120 GENERATOR PARALLELING

LEARNER'S GUIDE

GENERAC® | INDUSTRIAL POWER

WELCOME

Professional Development Seminar Series

Standby power systems are increasingly in demand. Commercial, industrial, municipal and healthcare facilities are just a few of the markets that require backup power. Generator paralleling is a crucial part of the process when designing a system.

The ever-changing requirements of the power generation industry, coupled with requests for additional training, has prompted Generac Power Systems to develop this training program.

Titled the Generac Power Systems Professional Development Seminar Series, this program consists of individual training modules that provide both theoretical and practical information. Each module is 90 minutes in length and each incorporate proven learning methodology to ensure a positive experience. These modules are designed to broaden the learner's understanding of topics such as:

- Current Technologies
- Sizing
- Codes & Standards
- Switching Technologies
- Reliable Design Characteristics
- Paralleling
- Engines and Alternators
- Controls
- Emissions

THE MODULE IN PERSPECTIVE

PURPOSE:

This course introduces you to the concept of parallel generator operation. It describes when and why paralleling is used along with special technical considerations including synchronization, load sharing and protection. Integrated versus traditional paralleling implementations are discussed along with their functional and economic considerations. The benefits of an "integrated" parallel system over a single generator application are also discussed.

TIME:

- 90 minutes of Classroom Instruction
- 30 minutes for Final Assessment

LEARNING OBJECTIVES:

Upon completion of this seminar, participants should be able to:

- Describe the concept of creating larger power systems using paralleled generators.
- Describe generator to grid and generator to generator configurations.
- Describe the key differences between the "Traditional" approach to parallel generator systems and today's "Integrated" approach.
- Describe the electrical requirements needed for proper operation of parallel operation.
- List and describe the functional and economic limitations of "Traditional" generator paralleling.
- List and describe the key functional and economic benefits of the "Integrated" approach to generator paralleling.
- List and describe the key functional and economic benefits of an "Integrated" parallel system over a "Single" generator system.
- Describe different paralleling approaches used by various manufacturers of generator systems.

CONTINUING EDUCATION:

Upon successful completion of this seminar, participants will be awarded a certificate of achievement identifying the seminar title, 2.0 PDHs (Professional Development Hours) and 0.2 CEUs (Continuing Education Units).
Successful completion of a PDSS seminar requires that the participant have:

1. Attended the complete seminar
2. A minimum score of 80% on the Final Assessment

TRAINING AT A GLANCE

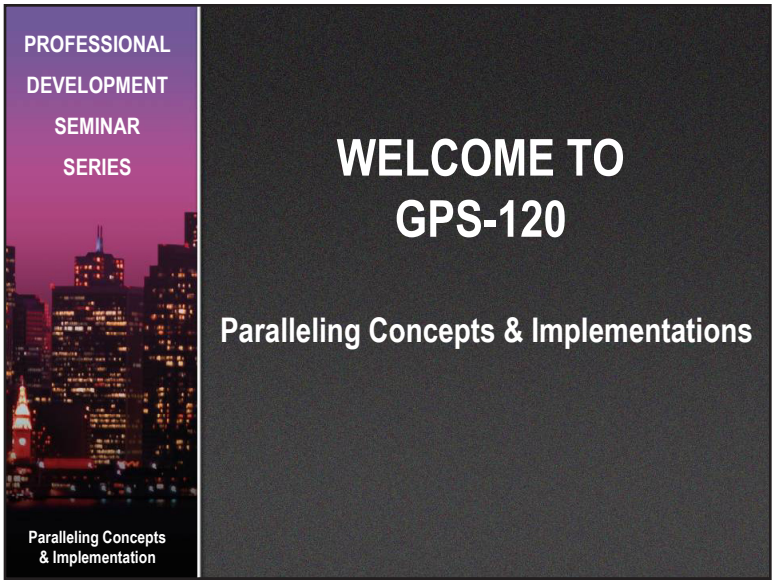
TIME	LESSON	DESCRIPTION
5 minutes	Introductions	Participants and trainer should become briefly acquainted. The trainer welcomes participants and conducts an opening icebreaker activity.
15 minutes	Lesson 1 What is Paralleling?	Conceptual overview of paralleling generators, including generator-to-generator and generator-to grid. The benefits of parallel operation will be discussed along with a look at traditional parallel approaches and their limitations.
10 minutes	Lesson 2 What is Required to Parallel?	A discussion of today's approach to parallel operation. Multi-function digital controllers will be described along with switching integration. A typical sequence of operation will be illustrated.
10 minutes	Lesson 3 What is an Integrated Approach to Paralleling?	The generator is a clean power source, but when applied to loads with high harmonic content, the generator voltage may become significantly compromised with harmonic voltage distortion. This lesson discusses various methods used to reduce these harmonic issues.
10 minutes	Lesson 4 Integrated vs. Traditional implementations	A comparison of traditional and integrated parallel approaches is discussed with the focus being on the increased reliability of integrated systems.
15 minutes	Lesson 5 Integrated Paralleling vs. Single Generator	A comparison between integrated paralleling and single generator use is discussed. Issues of reliability, scalability, cost, installation, maintenance, and serviceability will be evaluated.
10 minutes	Lesson 6 Various Manufacturer's Integrated Approaches	Brief descriptions of the approaches various manufacturers are taking to implement integrated paralleling.
10 minutes	Lesson 7 One-lines & Footprint Comparisons	Examples of one-line footprint comparisons with illustrations of integrated, traditional, and single generator systems.
5 minutes	Conclusion	The trainer will review the objectives of the class and discuss how each objective was accomplished. An evaluation will be given out with which participants can provide feedback about the course. An assessment will also be given to each participant to evaluate the skills and knowledge they received from the course.

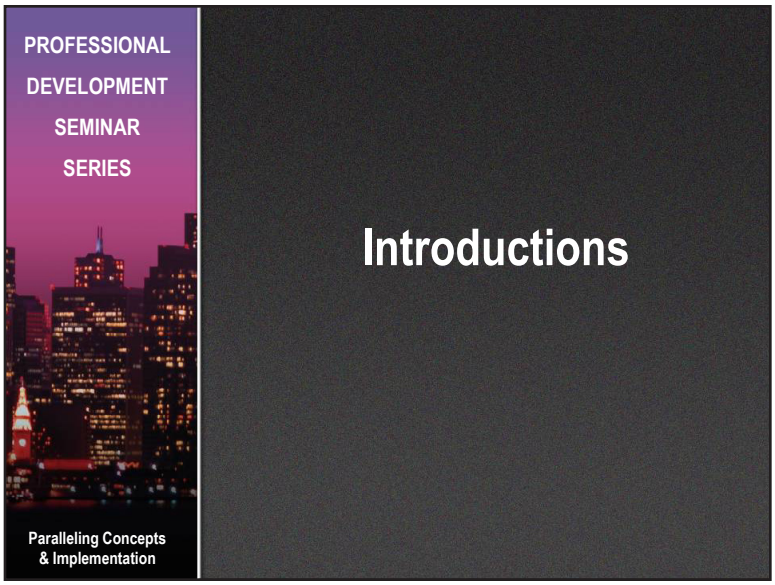
INTRODUCTION

TIME: 5 minutes

OBJECTIVE:

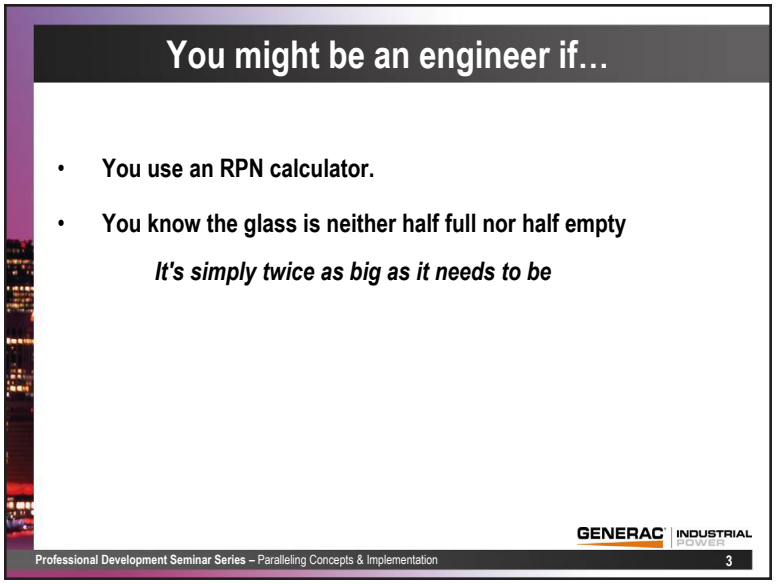
The introduction is an opportunity for the trainer and participants to become familiar with each other. This period will discuss the topics to be covered, capture initial questions and introduce generator paralleling.

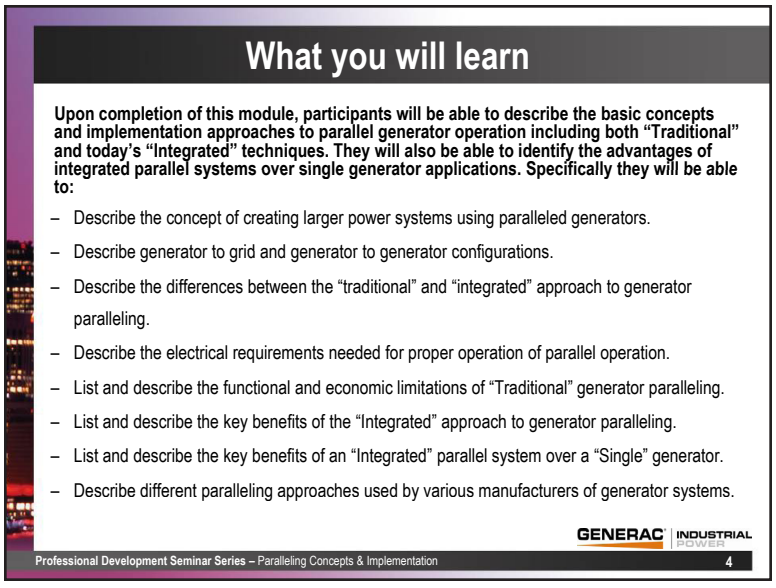




NOTES

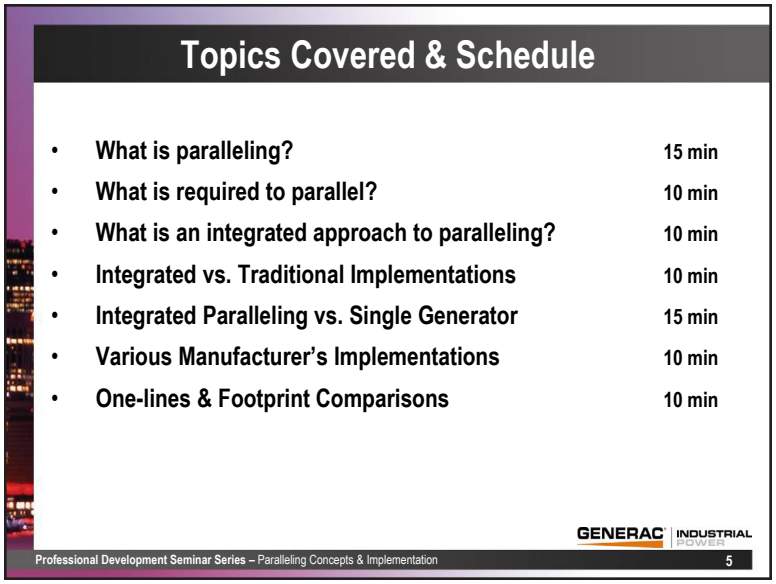
INTRODUCTION





NOTES

INTRODUCTION



NOTES

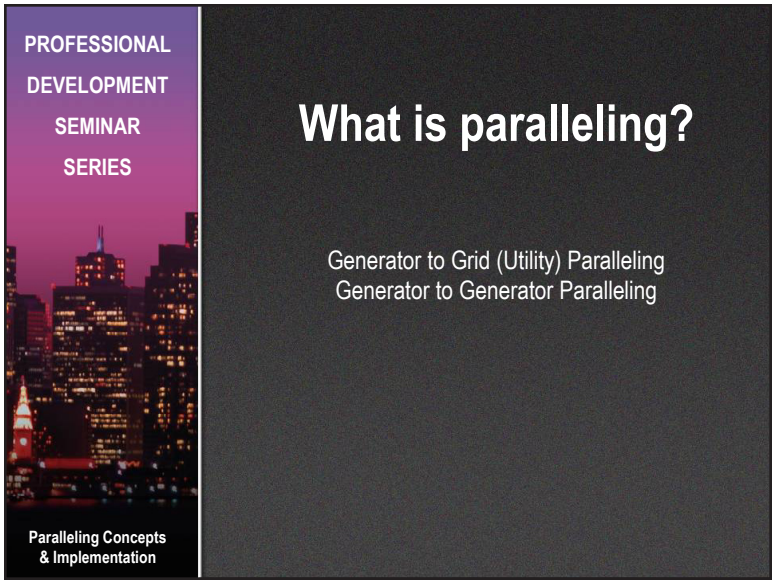
1. What is Paralleling?

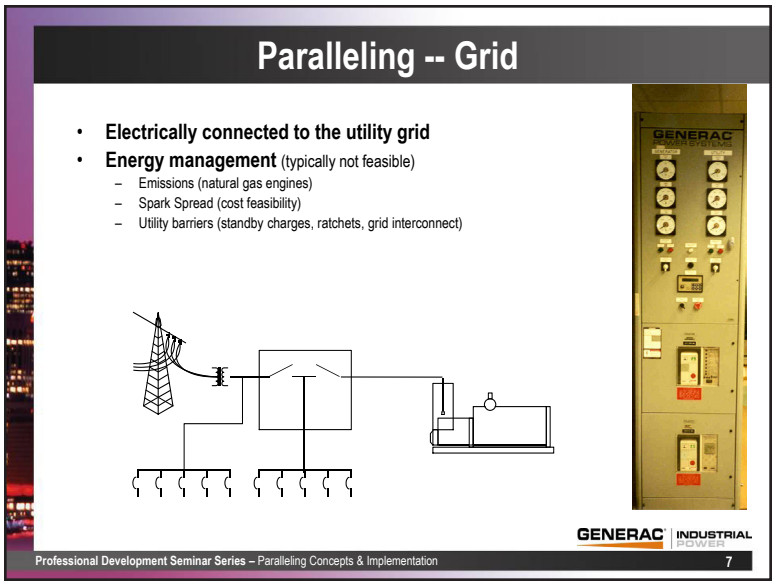
TIME: 15 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be able to describe the basic concepts of paralleling generator operation. Specifically, they will be able to:

- Describe the differences between generator to grid and generator to generator parallel configurations
- Describe the benefits of parallel generator operation
- Describe traditional parallel generator systems and their limitations



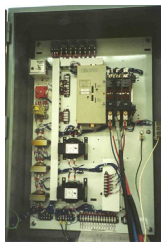


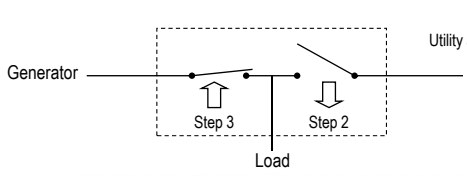
NOTES

1. What is Paralleling?

Paralleling – Grid "Momentary"

- **"Make-before-break" transfers**
  - CTTS (less than 100 msec)
  - Soft-load Closed transition (few seconds)
  - Synchronize the generator to the utility momentarily
  - Exercise with load
  - No outage on retransfer



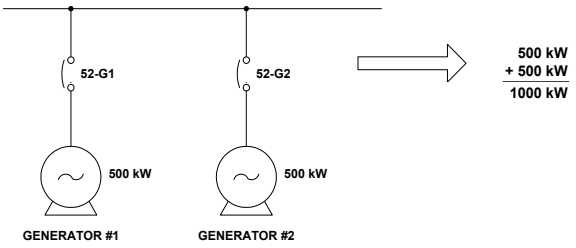


GENERAC INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 8

Paralleling – Gen to Gen

- **What is a paralleling system?**
  Two or more generators are electrically coupled together using special equipment to form a larger capacity power source.



GENERAC INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 9

NOTES

1. What is Paralleling?

Paralleling – Gen to Gen

- **Why use a paralleling system?**
  - Reliability
    - Accepted market reliability for single engine is 98-99%
    - Redundant systems offer multiple nines reliable for the critical loads
      - N+1 reliability (99.96 to 99.99%)
      - N+2 reliability (99.9992 to 99.9999%)
  - Scaleable
    - Ability to expand as your client's needs grow
    - Don't over build – preserve capital
  - Serviceable
    - Protect the critical loads while servicing the generator(s)

GENERAC | INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 10

Paralleling – Gen to Gen

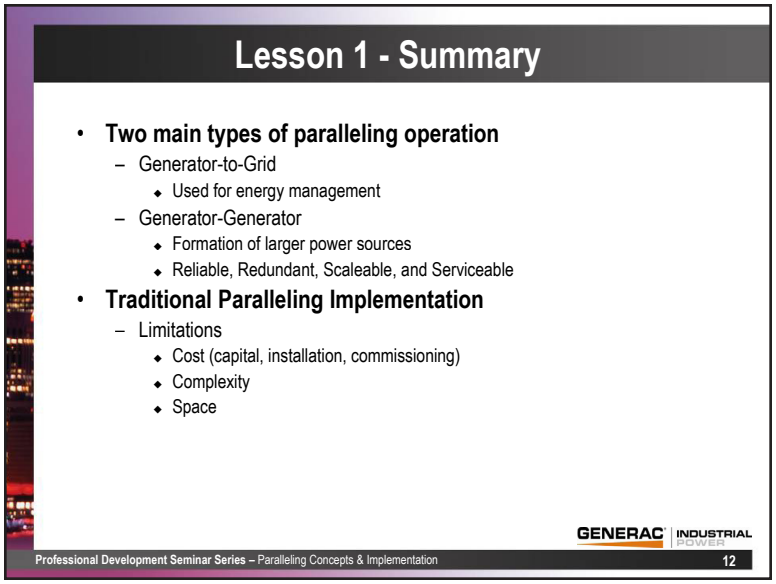
- **Why not use a paralleling system?**
  - Traditional implementations have limitations
    - Cost (capital, installation, commissioning)
    - Complexity
    - Space

GENERAC | INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 11

NOTES

1. What is Paralleling?



NOTES

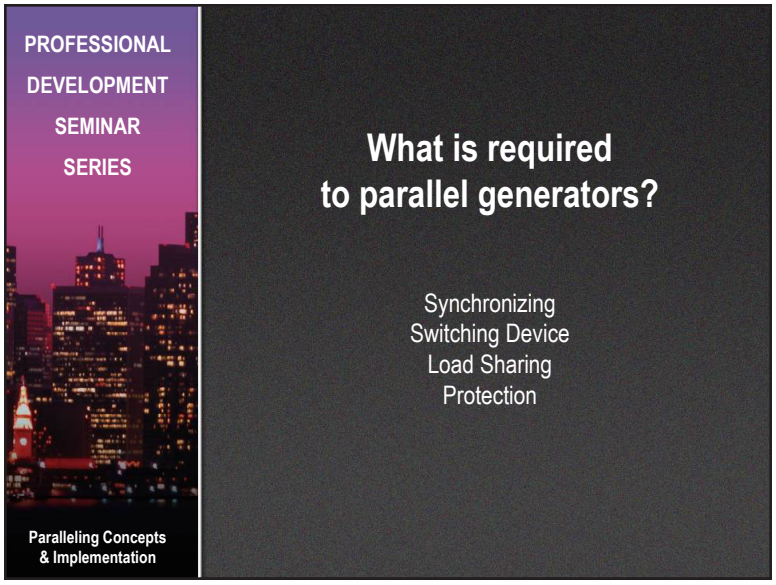
2. What is Required to Parallel?

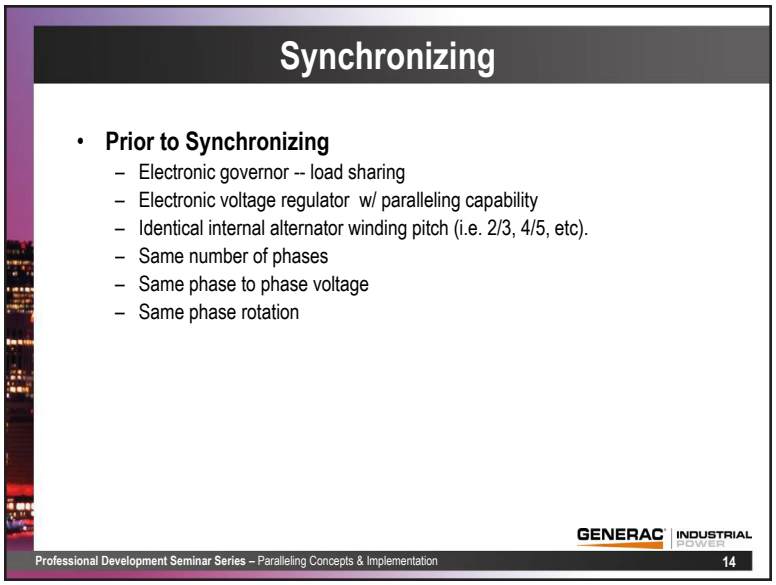
TIME: 10 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be able to identify and describe the basic requirements for parallel generator operation. Specifically, they will be able to:

- Describe the contacts used to connect generator to generator output
- Describe the functional differences between Breakers and Contactors
- Describe the Synchronizing process
- Describe Load Sharing
- Describe System Protection.



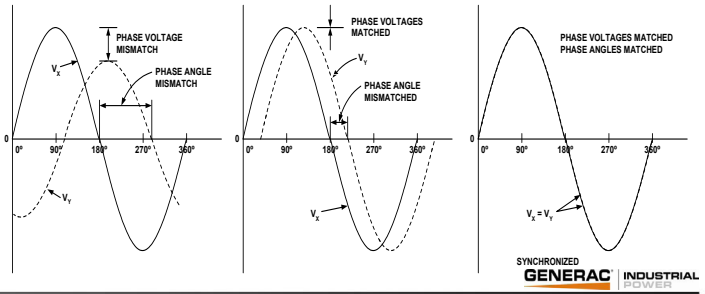


NOTES

2. What is Required to Parallel?

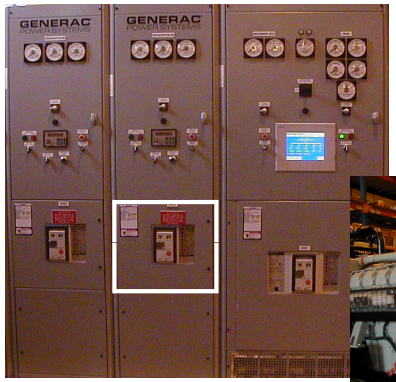
Synchronizing

- **Electrically <u>locking</u> two "machines" together**
  - Voltages matched
  - Frequencies matched + Slip frequency offset
  - Phase angles matched



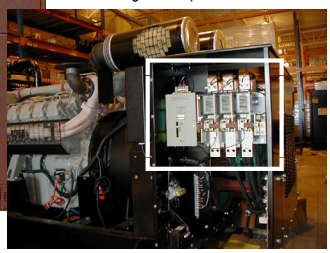
Professional Development Seminar Series – Paralleling Concepts & Implementation 15

Contact to Parallel Across



Traditional Panel Board Method

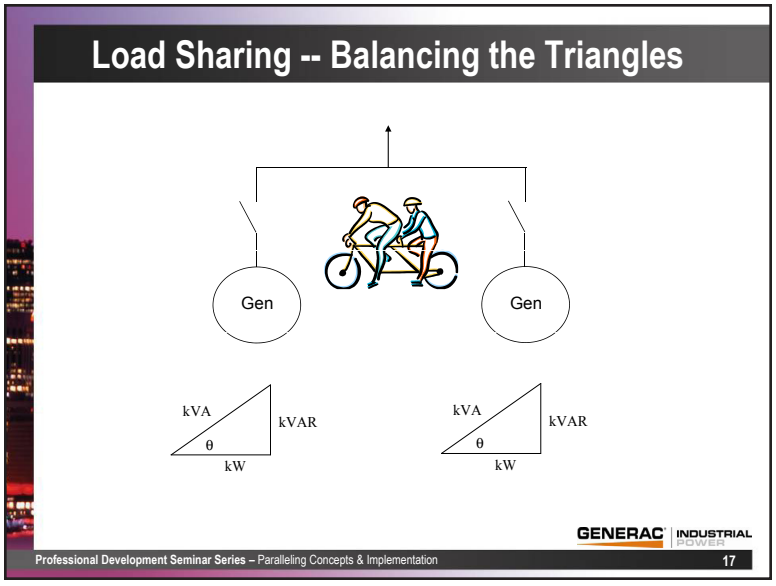
Integrated Implementation

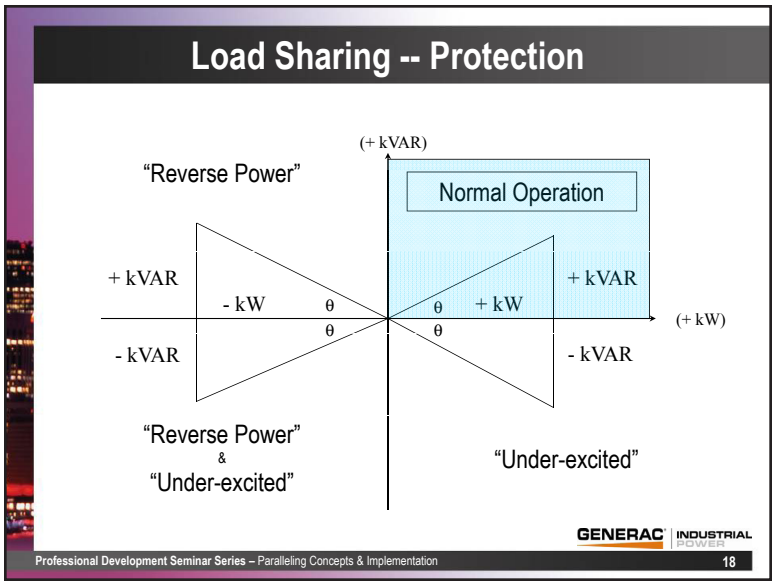


Professional Development Seminar Series – Paralleling Concepts & Implementation 16

NOTES

2. What is Required to Parallel?



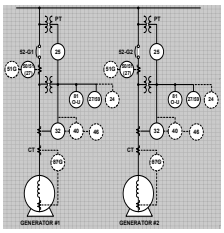


NOTES

2. What is Required to Parallel?

Protection

- **Synchronizing process**
  - 25 sync check relay
- **Real power system (governor & engine)**
  - 32 reverse power
  - 81 o/u frequency protection
- **Reactive power system (regulation & excitation)**
  - 27 / 59 voltage protection
  - 24 over excitation & volts/hz
- **Cabling & alternator**
  - 50 / 51 Overcurrent



GENERAC INDUSTRIAL POWER

Lesson 2 - Summary

- **Basic Paralleling**
  - Synchronizing (align waveforms of the alternators)
    - Voltage, frequency, phase angle
  - Contacts to connect generator to generator
  - Load Sharing (balance and control output power from each unit)
  - Protection (means to protect system against equipment failure)

GENERAC INDUSTRIAL POWER

NOTES

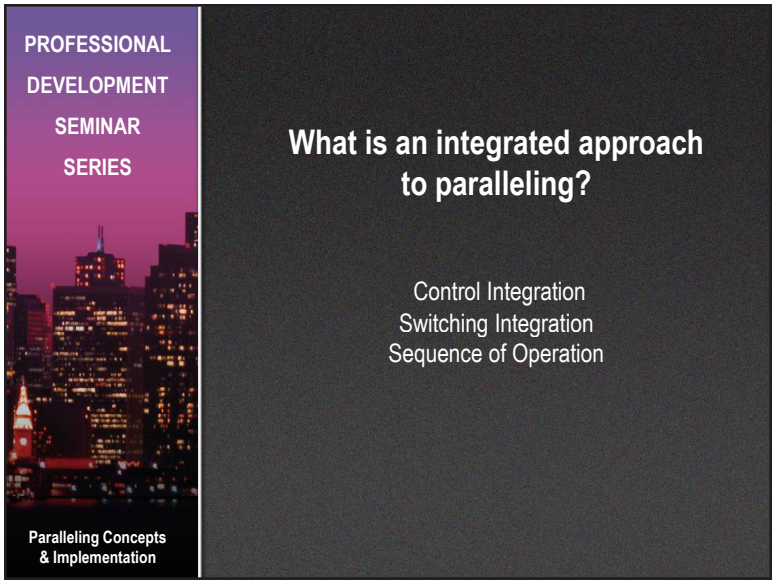
3. What is an Integrated Approach to Paralleling?

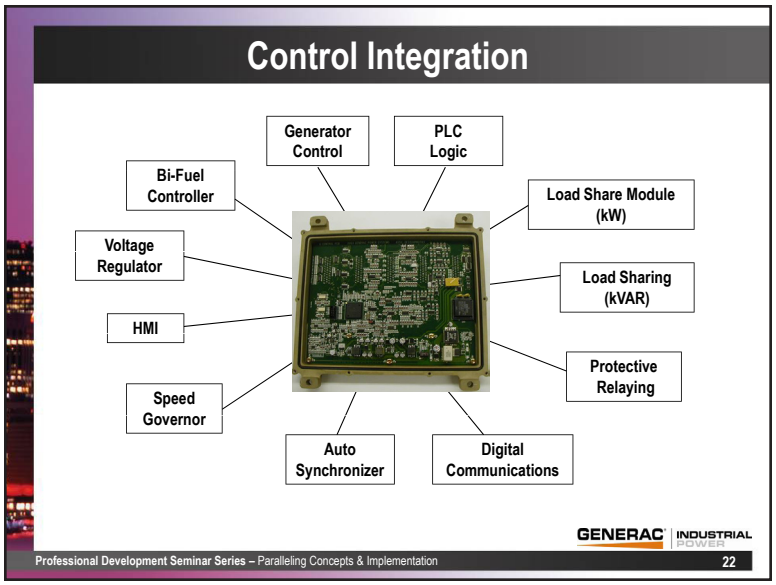
TIME: 10 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be able to describe a modern day "Integrated Approach" to parallel generator operation. Specifically, they will be able to:

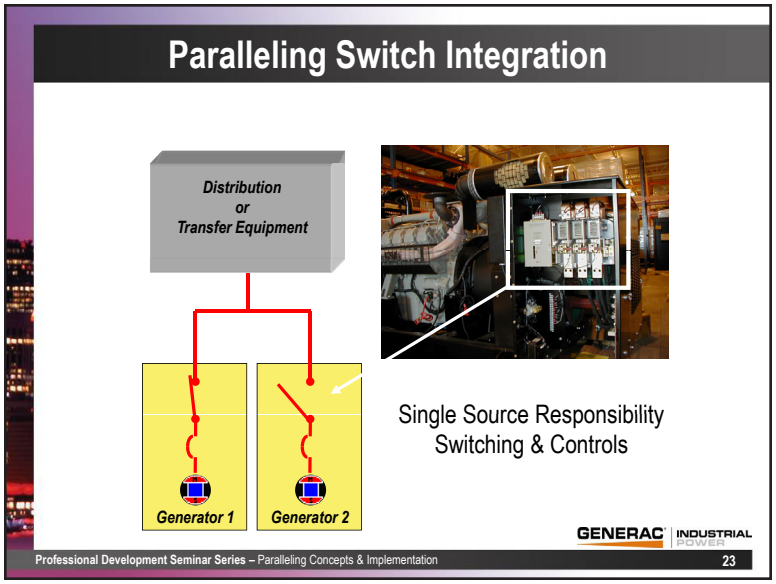
- List the various functions of a multi-function digital controller
- Describe the switching integration
- Describe the typical sequence of operation of a parallel system

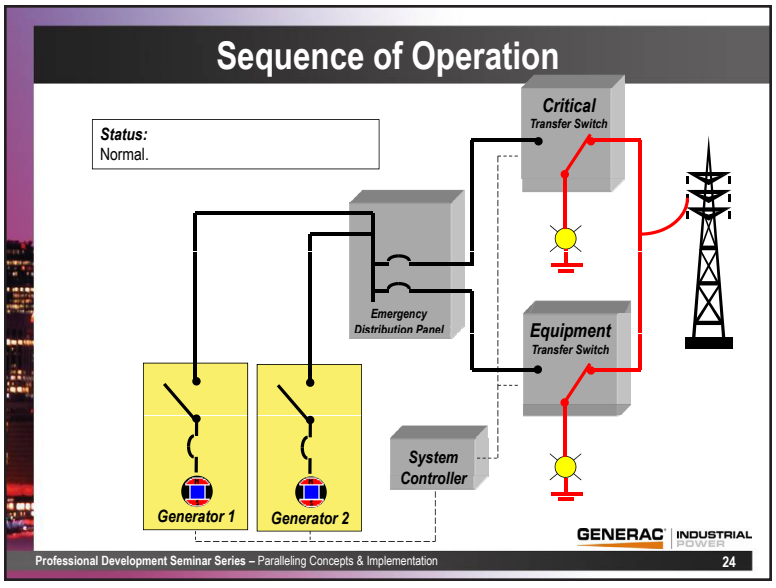




NOTES

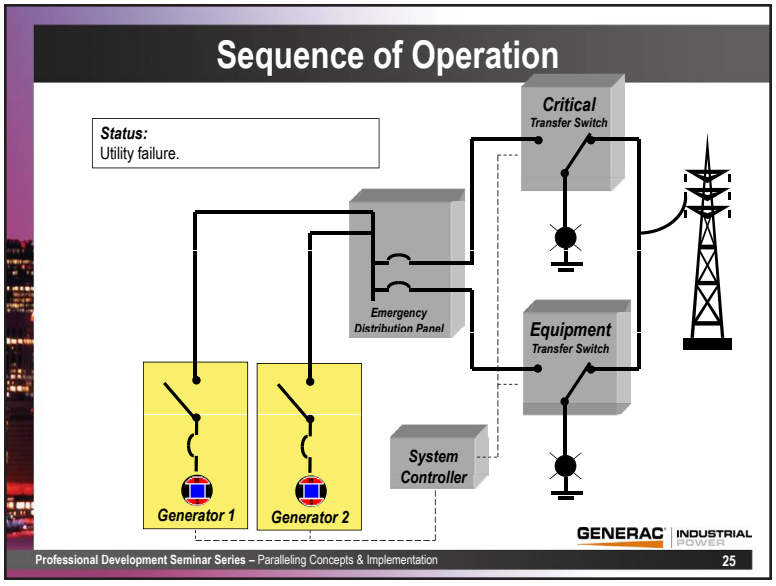
3. What is an Integrated Approach to Paralleling?

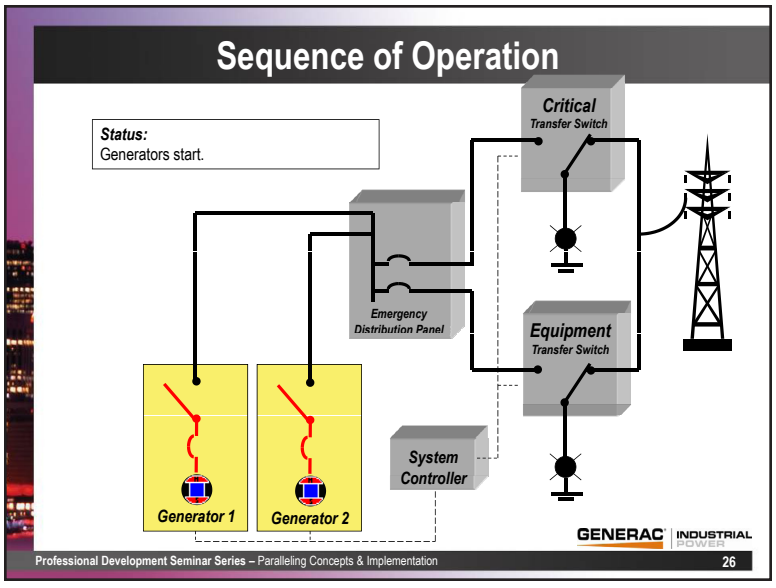




NOTES

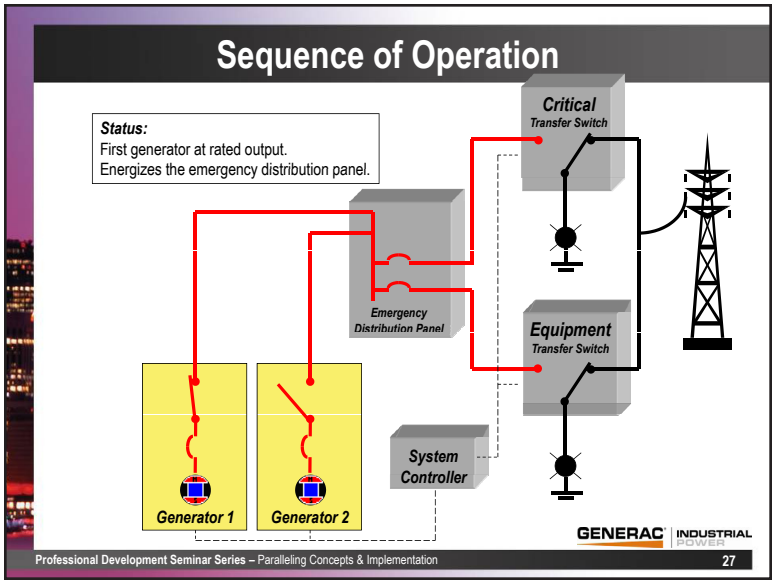
3. What is an Integrated Approach to Paralleling?

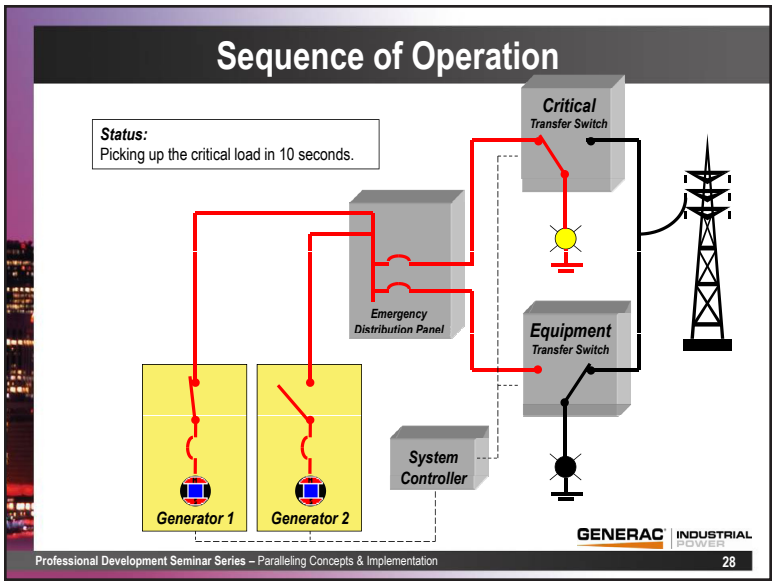




NOTES

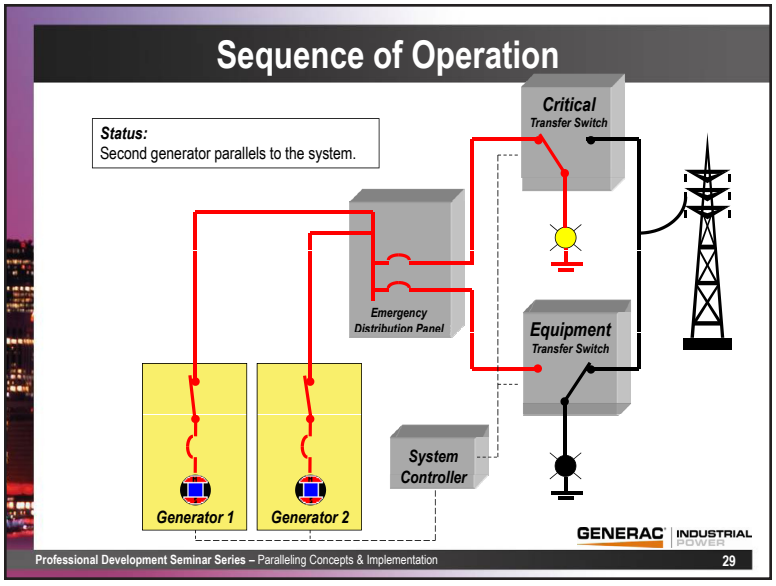
3. What is an Integrated Approach to Paralleling?

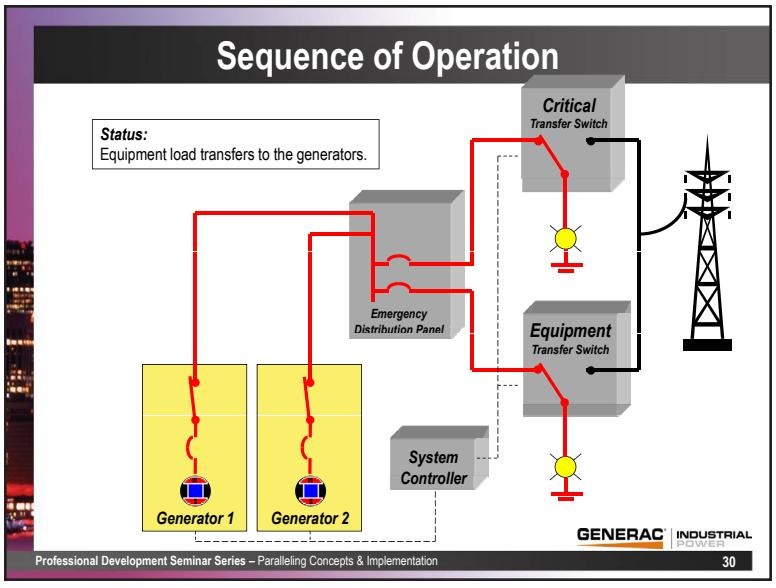




NOTES

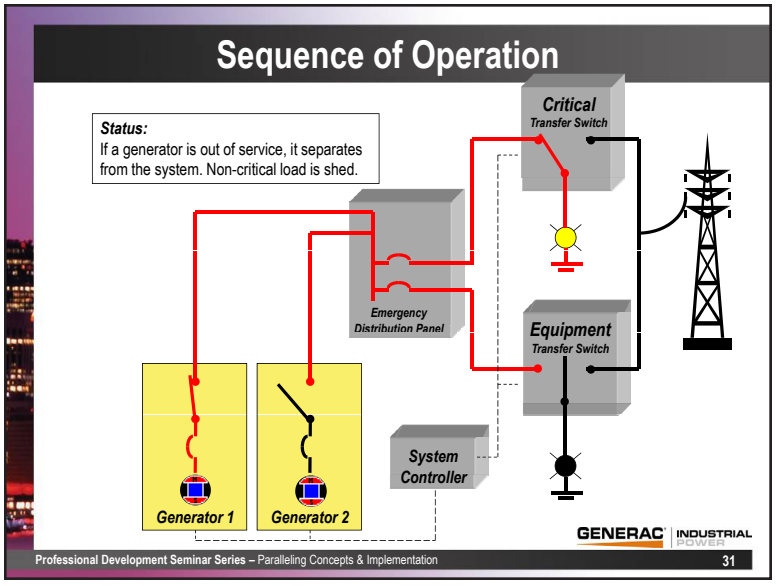
3. What is an Integrated Approach to Paralleling?

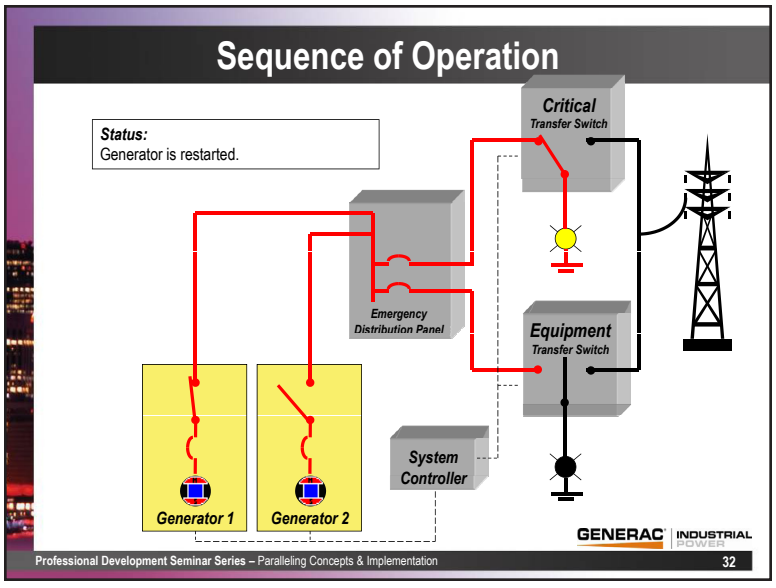




NOTES

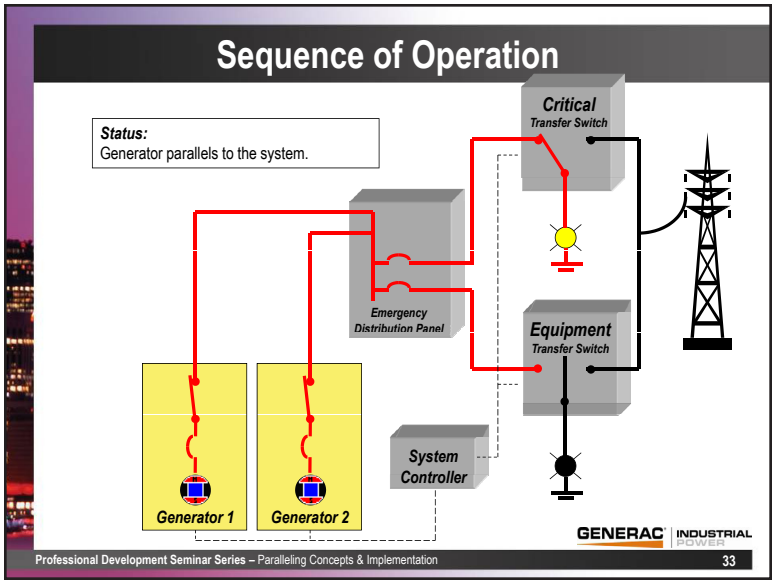
3. What is an Integrated Approach to Paralleling?

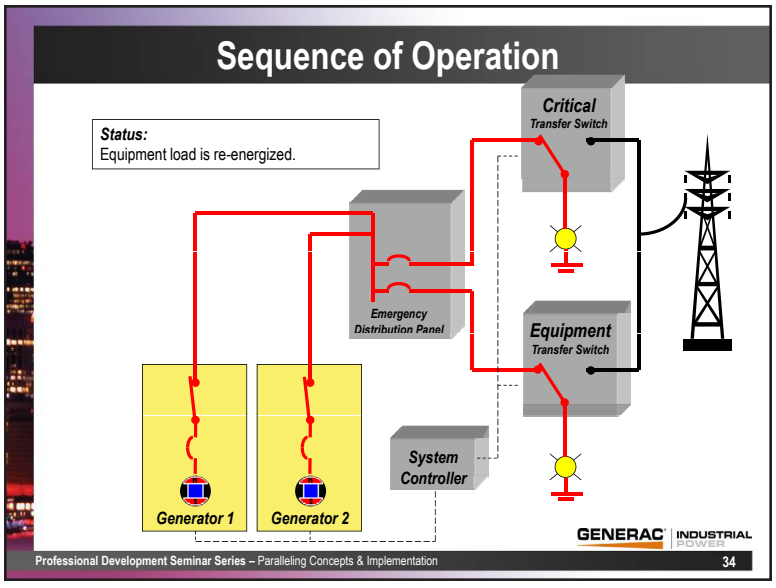




NOTES

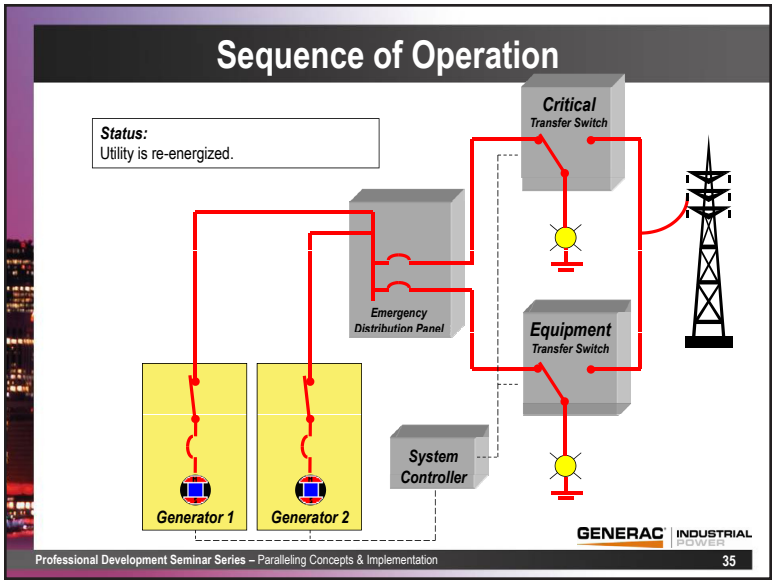
3. What is an Integrated Approach to Paralleling?

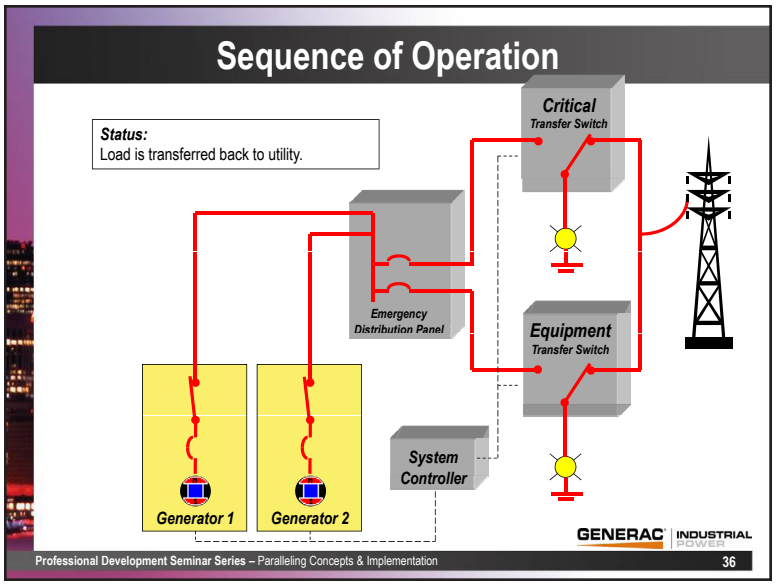




NOTES

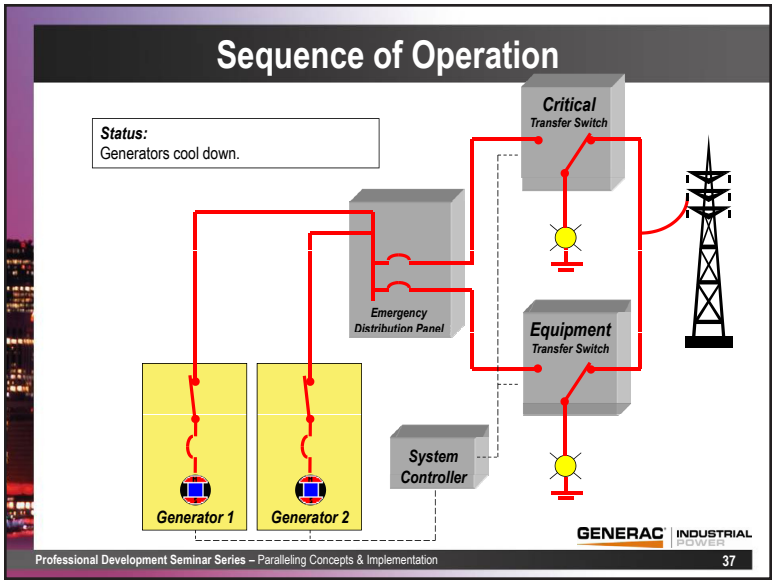
3. What is an Integrated Approach to Paralleling?

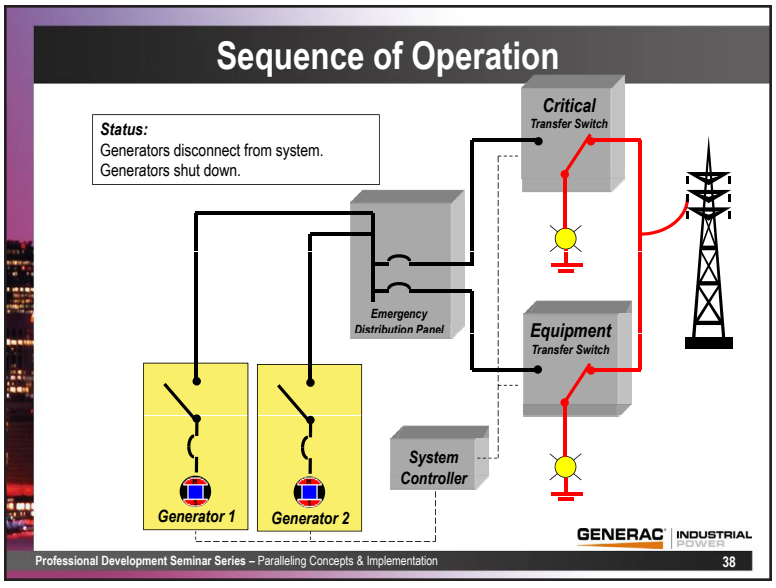




NOTES

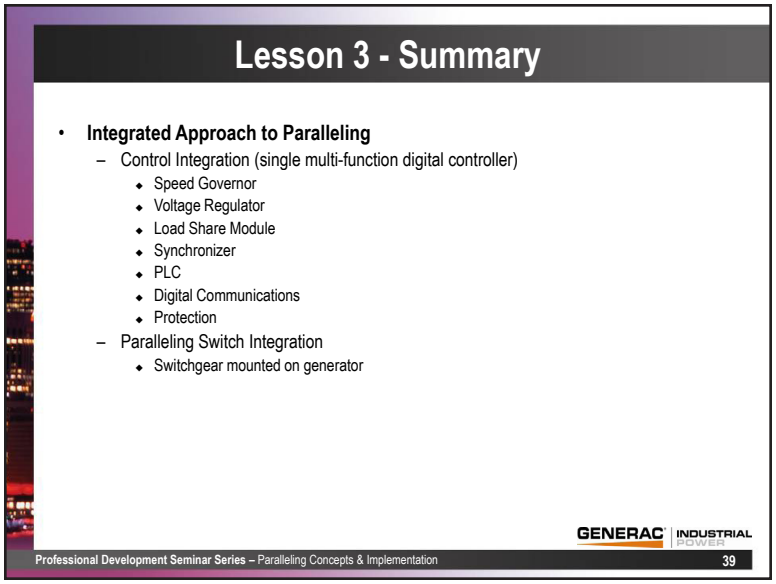
3. What is an Integrated Approach to Paralleling?





NOTES

3. What is an Integrated Approach to Paralleling?



NOTES

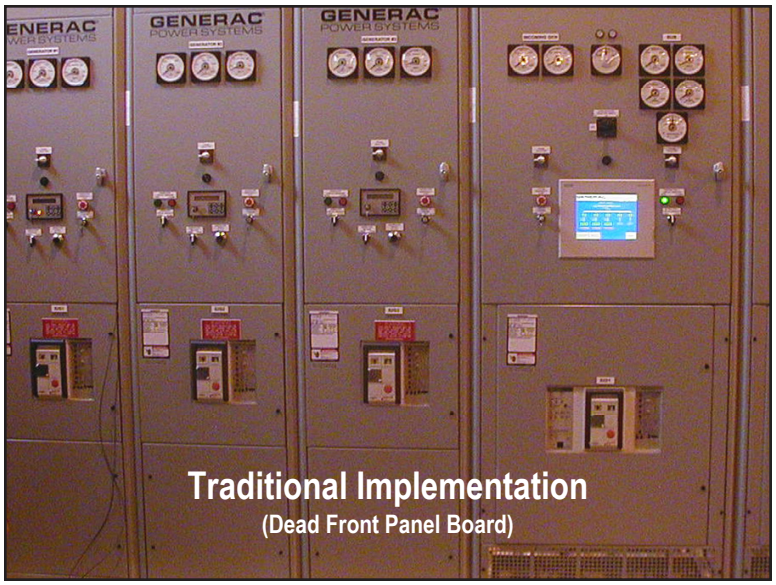
4. Integrated vs. Traditional implementations

TIME: 15 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be able to explain the differences between "Traditional" parallel generator systems and today's "integrated" approach. Specifically they will be able to:

- Describe the differences in control and switchgear configurations
- Describe the limitations of the "Traditional" approach to paralleling
- List and describe the complexity issues of the "Traditional" approach
- List and describe the benefits of the "Integrated" approach to paralleling



NOTES

4. Integrated vs. Traditional implementations

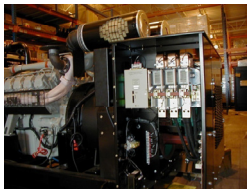
Traditional Implementation

- **Limitations of dead front panel board approach?**
  - Higher capital cost
  - Higher installation cost
  - Space constraints
  - Complexity
  - Installation time
  - Commissioning time

GENERAC | INDUSTRIAL POWER

Switching Reliability

- **Breakers or Contactor**
  - What is the design / intent of a breaker?
  - What is the design / intent of an contactor?
  - Which has mechanics optimized for repetitive switching?
  - Which has replaceable contacts?



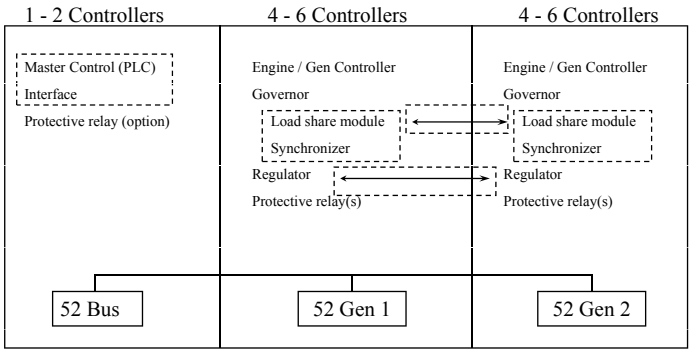
GENERAC | INDUSTRIAL POWER

NOTES

4. Integrated vs. Traditional implementations

Controller Reliability

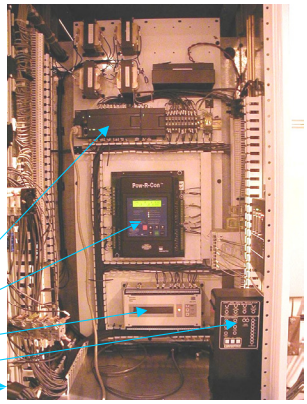
- **Limitation of traditional implementation?**
  - Controller complexity, installation and commissioning time



GENERAC | INDUSTRIAL POWER

Reliability of Custom/Complex Installs

- **Custom hardware**
- **Custom software**
- **Limited failure mode analysis**
  - Beta hardware schematic
  - Beta PLC software
- **Multiple suppliers**
- **Sequenced by PLC**
- **Hard to troubleshoot**
- **Hard to calibrate**



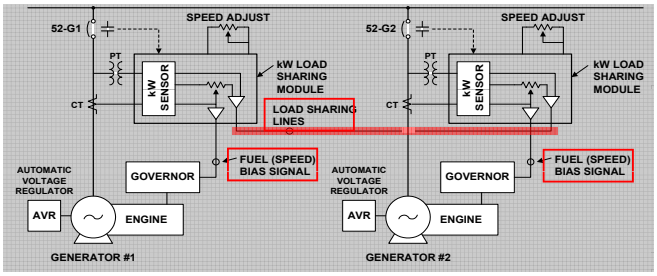
GENERAC | INDUSTRIAL POWER

NOTES

4. Integrated vs. Traditional implementations

Reliability of Load Sharing

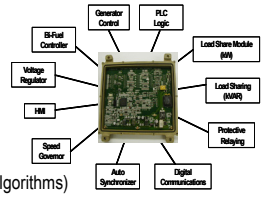
- **Traditional load sharing**
  - Isochronous load sharing
  - Reactive cross current
  - Struggles with calibration, stability, electrical noise



GENERAC INDUSTRIAL POWER

Reliability through Integration

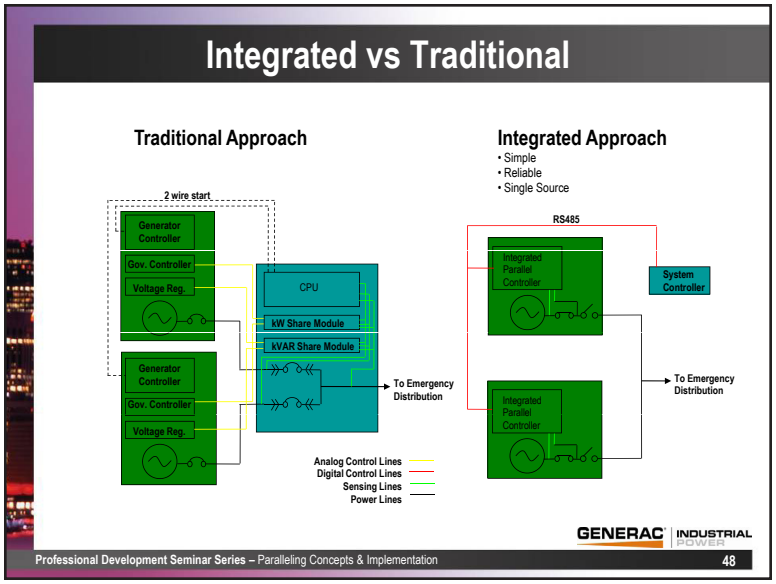
- **Controller issues are corrected**
  - An integrated, all digital approach
    - Reduces interconnecting wiring (communications)
    - Proven hardware & software (not one-off designs)
    - Removes calibration issues (self tuning)
    - Enhances load balancing stability (inherently stable algorithms)
    - Improves tolerance to electrical noise (no load share lines)
    - Removes system failure modes (load share lines & PLC)
    - Maximizes system reliability
    - System remains operational without master control

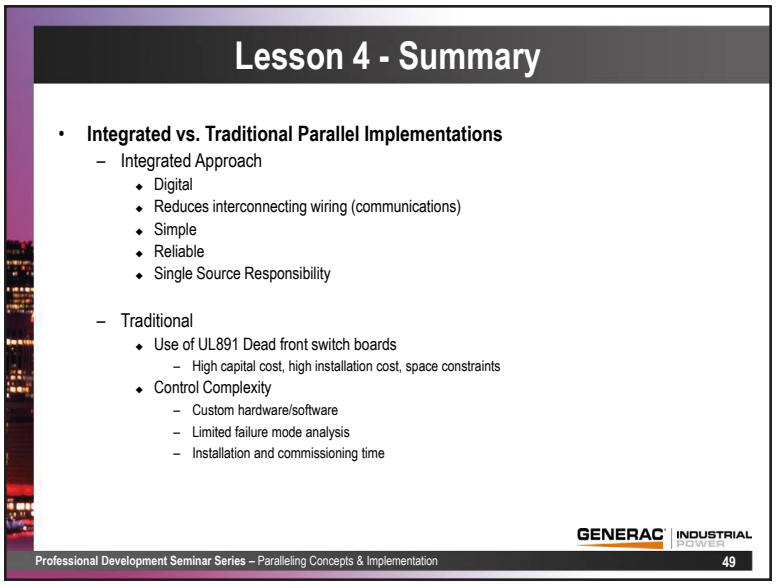


GENERAC INDUSTRIAL POWER

NOTES

4. Integrated vs. Traditional implementations





NOTES

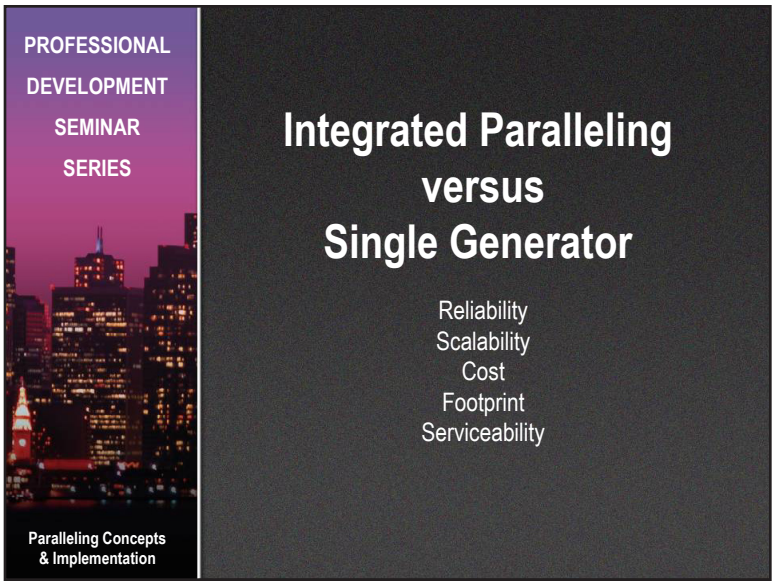
5. Integrated Paralleling vs. Single Generator

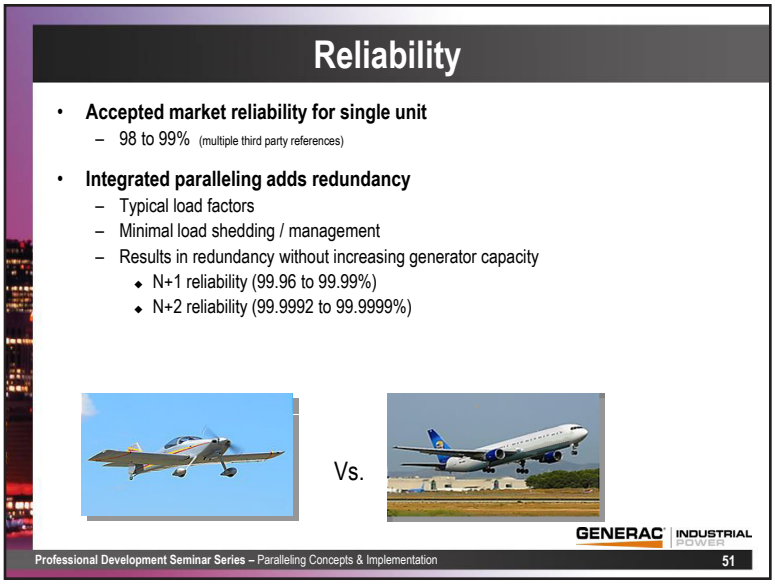
TIME: 10 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be able to describe the benefits of integrated parallel generator systems over single generator systems. Specifically, they will be able to:

- Describe the reliability of an integrated system
- Describe the scalability of an integrated system
- Describe the cost savings in capital, installation and maintenance of an integrated system
- List and describe the serviceability features of an integrated parallel system





NOTES

5. Integrated Paralleling vs. Single Generator

Scaleable

- Start with a single generator
- Planned growth
- Unanticipated growth
- Lower initial investment
- Budget / capital constraints
- Protection against uncertainty

Single generator implementations offers no cost effective expansion capabilities – This solution typically uses sizing safety factors to protect against uncertainty and load growth.

GENERAC | INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 52

Total Owning Costs

- Integrated Paralleling meets Single Generator's Cost
  - Capital cost
    - Optimizing market engine pricing (high volume engines)
  - Installation cost
    - Same amps, same distance
    - Potential for smaller cabling (NEC 800 amp breaker roundup rule)
    - Potential crane reduction (40 ton vs. 80 ton)
    - Pad thickness reduction (6" vs. 10-12")
  - Maintenance cost
    - More manageable fluids
    - Comparable consumables
    - "Ask for PM quotations for both options"

GENERAC | INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 53

NOTES

5. Integrated Paralleling vs. Single Generator

Foot Prints

- Foot Print Size vs. Location Flexibility
  - Foot print examples
    - 1000kW (26.1' x 8.4')
    - 2 x 500kW (19.2' x 13.5')
    - 1500 kW (33.3' x 8.4')
    - 2 x 750 kW (16.9' x 16.5')
  - Location flexibility
    - Various layouts
    - Units can be separated
    - Parking garages
    - Rooftops

GENERAC | INDUSTRIAL POWER

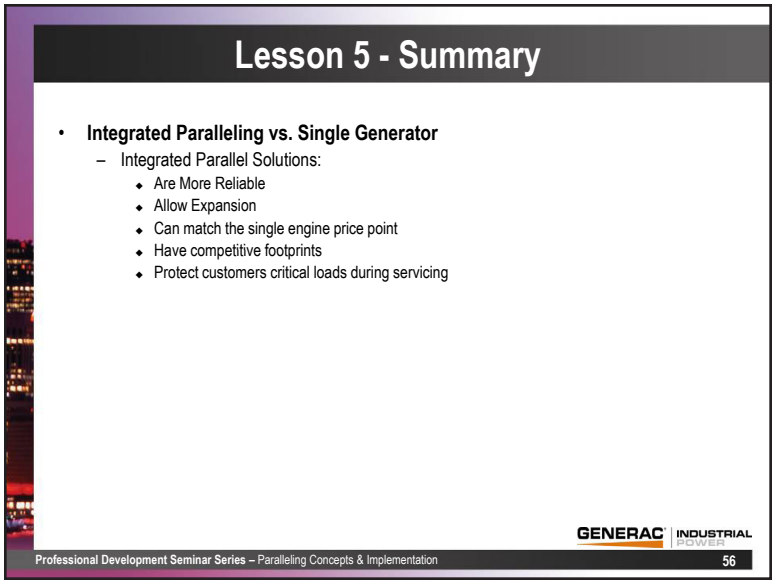
Serviceable

- Single generator implementations
  - Limited to no protection while servicing
- Can your critical loads go without protection?
  - Oil & coolant changes
  - Belts, hoses, batteries
  - Load bank connection
  - Minor repairs
  - Major repairs
- At what point do you bring in a rental?
  - Change-over time
- Paralleled implementations provide protection duri

GENERAC | INDUSTRIAL POWER

NOTES

5. Integrated Paralleling vs. Single Generator



NOTES

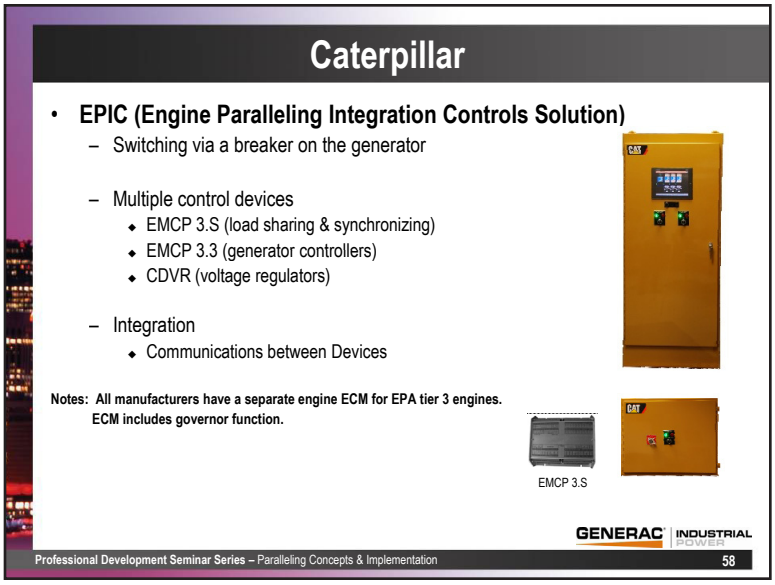
6. Various Manufacturer's Integrated Approaches

TIME: 10 minutes

OBJECTIVES:

Upon completion of this lesson, participants will be familiar with parallel generator approaches currently being implemented by other manufacturers. Specifically, the following manufacturers will be identified:

- Caterpillar
- Generac
- Cummins
- Kohler/SDMO

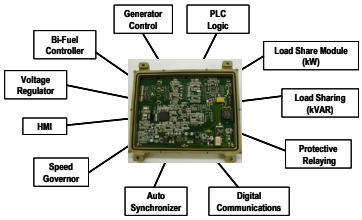


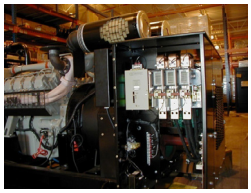
NOTES

6. Various Manufacturer's Integrated Approaches

Generac

- **Modular Power System (MPS)**
  - Paralleling switching device mounted on the generator
  - Single controller per generator
    - All control functions within single controller
    - Master control using same hardware
    - Limited interconnecting wiring (all digital)
    - Parallel tests at factory



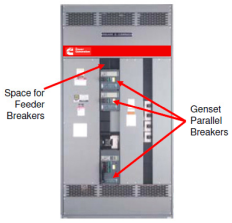


GENERAC | INDUSTRIAL POWER

Professional Development Seminar Series – Paralleling Concepts & Implementation 59

Cummins

- **PowerCommand Digital Paralleling (PCC3200)**
  - Typically use dead front panel board switching
  - Option for Square D electric operated molded case breakers
  - Single controller per generator
    - All control functions within single controller (card rack approach)
    - PLC based master control / load management



GENERAC | INDUSTRIAL POWER

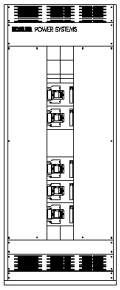
Professional Development Seminar Series – Paralleling Concepts & Implementation 60

NOTES

6. Various Manufacturer's Integrated Approaches

Kohler

- **Decision-Maker Paralleling Systems**
  - Square D electric operated molded case breakers
  - Single controller per generator
    - All control functions within single controller (3 board implementation)
    - PLC based master control / load management



GENERAC | INDUSTRIAL POWER

Lesson 6 - Summary

- **Various Manufacturer's Integrated Approaches**
  - Manufacturers are taking steps to a more integrated approach
    - These approaches vary from digital communications with the generator controller and the use of digital load sharing,

      to

    - fully integrated controls and integrated switching.

GENERAC | INDUSTRIAL POWER

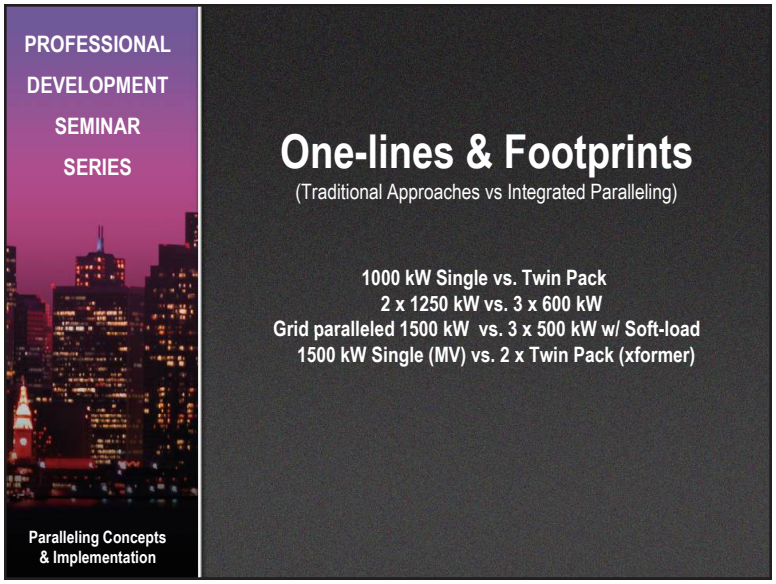
NOTES

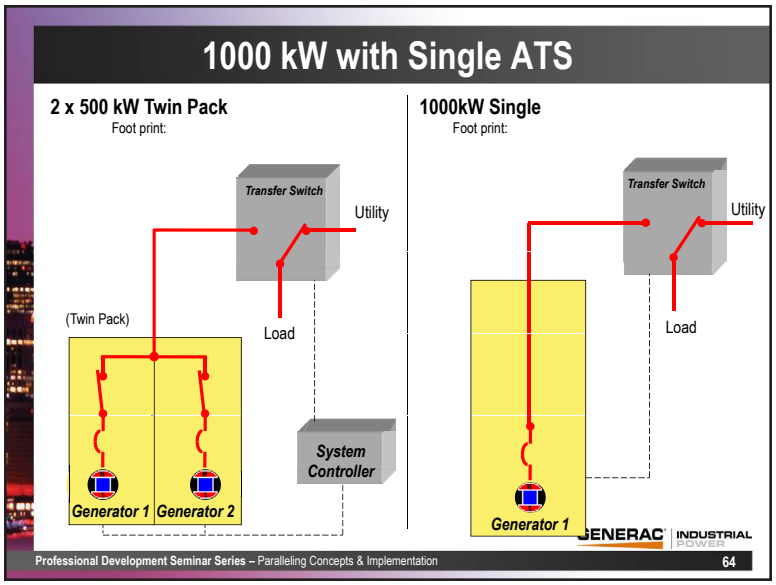
7. One-lines & Footprint Comparisons

TIME: 10 minutes

OBJECTIVES:

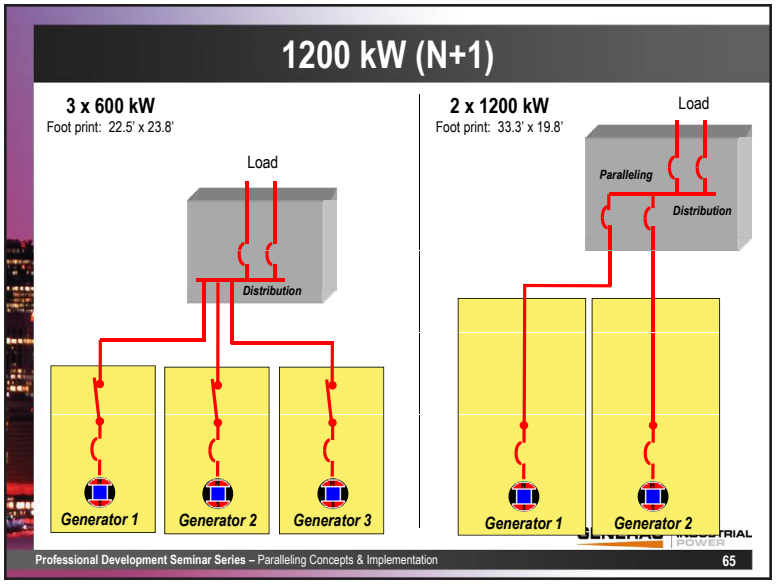
Upon completion of this lesson, participants will be familiar with a variety of one-line footprint comparisons

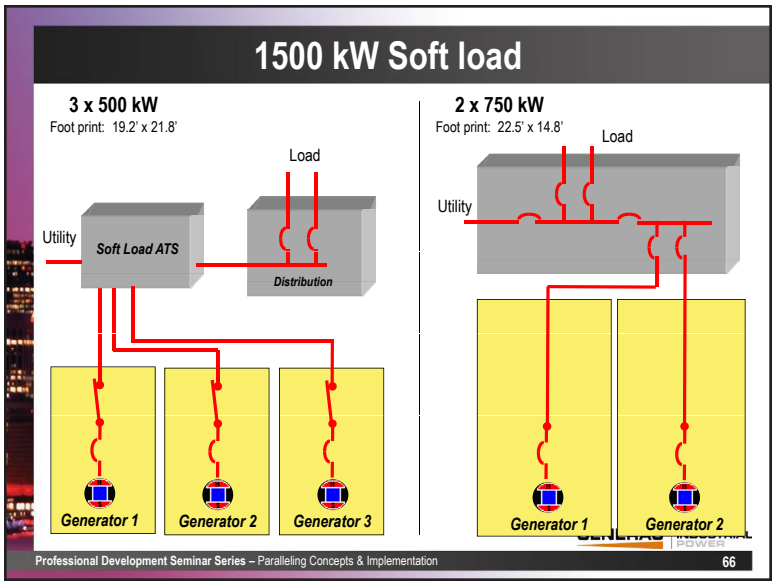




NOTES

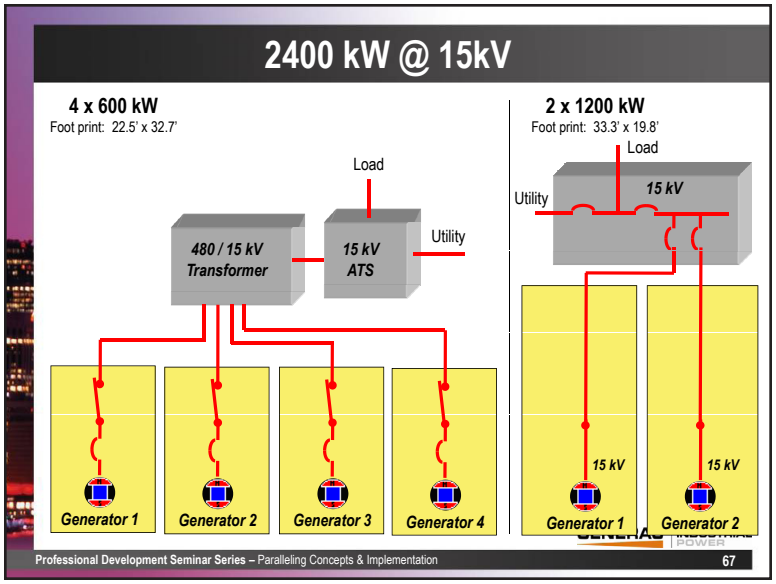
7. One-lines & Footprint Comparisons





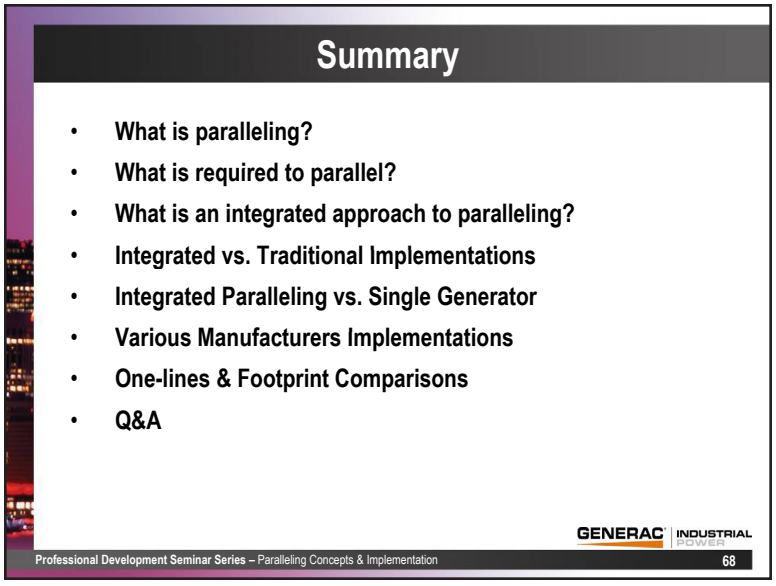
NOTES

7. One-lines & Footprint Comparisons



NOTES

CONCLUSION



NOTES

GENERAC®

Designing & Specifying Reliable Power Solutions

"An Integrated Approach to Paralleling Generators"

WHITE PAPER

INTRODUCTION

Parallel power solutions have always offered the standby generation marketplace significant advantages; however, the implementation of these solutions has been limited to mission critical applications and large kilowatt projects. This is largely due to the constraints in implementing traditional paralleling solutions. These constraints include costs, space, issues of single source responsibility, and a significant level of complexity. To access the benefits of parallel generation while removing the cost and complexity limitations, generator manufacturers need to integrate generator paralleling into the genset package.

The first step in evaluating parallel generation options is to acknowledge the benefits gained by placing multiple power sources in parallel. Some of these benefits include increased reliability, expandability, flexibility, serviceability and cost effectiveness.

BENEFITS OF PARALLELED GENERATION

Reliability

Parallel power generation is simply more reliable than single engine generator solutions. With multiple generators on call, redundancy is built-in and reliability is increased because each generator backs up the other. The resulting gains in reliability for the critical loads are significant. For example, if a standby generator has a reliability of 98% an N + 1 configuration has a reliability of 99.96% and an N + 2 configuration has a reliability of five nines. Many would interpret that to mean that redundancy is only gained with the additional cost of under-utilized additional generators -- not so. In many applications, the load requiring the highest degree of reliability is only a percentage of the total generation capacity. In these situations, parallel generation automatically provides redundancy for the most critical load, provided basic load shedding is implemented in the power system. Load shedding may be implemented through shunt tripping distribution breakers, driving transfer switches to a disconnected position, or interacting with building management systems.

Expandability

Many times when sizing generators, it is difficult to adequately plan for anticipated load growth. If growth projections are too aggressive, precious project capital is expended before it is necessary. If growth projections are too low, the facility may be left without reliable standby power or require expensive generator upgrades. An integrated approach to paralleling generators would allow generators to be added as needed. Wouldn't it be convenient to simply "plug and play" additional generation modules anytime it's required? Generation could be scaled to more precisely match load requirements as facilities grow or change. Smaller units of different kilowatt ratings could be combined in any combination to meet a particular load profile. For a growing facility, this expandability has

two advantages. First, it reduces the initial cost by allowing purchase of a more modest system that is scaled to initial needs and can be expanded as necessary. Second, it eliminates the need to estimate ultimate requirements and purchase a large and very expensive single engine unit suited to that projected need — which may or may not develop as anticipated. With an integrated paralleling system, generation capacity could be managed to match business realities:

- Lower initial investment
- Budget / capital constraints
- Controlled growth
- Unanticipated growth

Flexibility

Four–pole switches are sometimes, but not always, required for applications involving ground fault protection Utilizing multiple smaller generators instead of a single large unit solution offers greater application flexibility. This can be a significant advantage in meeting many site-specific logistical constraints. Multiple smaller generators offer greater weight distribution making roof-top installations more feasible. Smaller generators are also shorter and lower, providing flexibility in applications with height or depth constraints. In addition, the generators do not need to be located side by side or even together, thus providing significant installation flexibility for retrofit projects.

Serviceability

Multiple generator solutions also provide flexibility during service operations. With multiple generators available, unit(s) can be taken out of service for repair or scheduled maintenance without complete loss of a site's standby power. Remaining in-service units can still serve critical site loads. Though catastrophic failures of standby generators are not common, multiple generator solutions significantly mitigate the effects of such an event. The inherent redundancy of the system ensures backup power even during equipment failure and the capital cost to replace a smaller unit is a fraction of the large, single generator expense.

Cost Effectiveness

An ancillary benefit of using multiple smaller gensets is derived from the engine classification. Smaller generators use high volume, mass-produced over-the-road truck engines. These prime movers tend to be of extremely high quality and very reliable due to the level of tooling and plant automation utilized in their manufacture. This same automation along with market pressures and economies of scale make this engine class the lowest cost per kW for prime movers. When these high value prime movers are combined with internally integrated paralleling technology, paralleled generation systems can compete dollar for dollar against monolithic single engine solutions. In addition to capital cost, this engine class tends to have less expensive maintenance and replacement parts and the engines are more readily serviceable by on-road diesel technicians.

LIMITATIONS OF TRADITIONAL PARALLELING

Cost

Even though paralleled generation has all the previously identified benefits, its application has been significantly limited. Implementations were limited to mission critical applications in which cost was a secondary concern to power reliability or applications requiring power in excess of 2 MW (historically the largest cost effective single engine solution). Historically, paralleled power generation was accomplished through utilizing third party vendors that integrated UL891 dead front panel boards into generator paralleling switchgear. Though effective, this approach has its limitations. Cost is the most notable drawback. The capital cost for low voltage traditional generator switchgear is typically $20,000 to $25,000 per section. To parallel two generators (which typically

requires one section for each generator and a master control section) would cost $60,000 to $75,000. That is just the start of the entire project's expense.

Space

The switchgear needs dedicated floor space inside the building. Plan for each section to be 36" wide by 48" deep and 90" tall. Also plan for a minimum of 3' in front and 3' behind the switchgear cabinets. The switchgear lineup needs to be located in place and bus work may need to be reconnected.

Integration Issues

Plan on a week for the entire installation process. Once installed, plan on another week for startup and commissioning. This process requires the generator and switchgear technicians to be on-site and rarely goes smoothly. The only exception to this is for equipment that has been previously tested at the factory as an entire system (generators and switchgear). It soon becomes obvious to anyone running the numbers that the traditional approach to paralleling generators can only be justified for a limited number of high-end applications.

TRADITIONAL PARALLELING CONTROL COMPLEXITY

Additionally, this approach is less than optimal given the complexity of the control system. Each generator in the system typically includes four to six micro-controllers. These controllers are a combination of analog and digital technology from various manufacturers that are hardwired together into an amalgamated system. Thus a two generator paralleling system would require nine to fourteen controllers once the master control section is included in the controller count. It becomes apparent that these systems are more complex than they initially appear.

Speed Control

Each generator in the system incorporates an electronic governor function. For a mechanically injected engine the governor is typically a third party controller from companies like Woodward Governor Company, Barber Coleman, Governors of America, etc. For electronically injected engines, this function is internal to the engine management controller supplied by the engine manufacturer. This governor function normally controls engine speed and, as a result, generator frequency in what is called isochronous speed control. Basically, a speed governor is a simple PID (Proportional / Integrated / Derivative) controller that compares engine speed to a reference and then ramps the engine fuel rack open or closed.

This works fine for a single engine generator. However, when multiple generators are paralleled together the control parameter (engine speed) is locked into the speed of the other generators in the system. This creates a problem. The engine with a slightly lower speed set point will integrate its fuel setting closed and reverse power. The engine with a slightly higher speed set point will integrate its fuel setting open till it is carrying the entire system load or is at full throttle. The generators don't inherently share load. It's like a bicycle for two in which only one person is pushing power into the pedals.

Load Balancing

Enter the second controller. Each generator incorporates a loadshare controller that constantly tweaks the governor's speed reference for its engine. For this system to work, the loadshare controllers are interconnected with a loadshare line that shares information about expected load levels. Through constant speed reference changes, this system does balance load between the generators even though from a control loop standpoint it is inherently unstable. The weakness of this traditional approach is that it requires everything to work perfectly and unfortunately it tends to be sensitive to electrical noise. It is kind of like trying to balance a marble on the outside of a bowl by tipping the bowl left and right. You can do it if you're quick enough, but don't get distracted.

Synchronizing

The third controller is an auto synchronizer. This controller matches the sine wave of the generator with the sine wave of the generator bus and issues the command to close the breaker tying them together. This process tends to be very straightforward and easily accomplished. For some manufacturers, loadshare controllers and synchronizers are integrated into a single device.

Voltage Regulation

The fourth controller for each generator is the voltage regulator. The regulator is typically supplied by the alternator manufacturer or from independent third party controller companies like Basler Electric. This regulator function normally controls alternator voltage. Similar to the speed governor, the regulator is a simple PID controller that compares alternator voltage to a reference and then ramps the alternator excitation up and down. This works fine for a single generator; however, when multiple generators are paralleled together the control parameter (voltage) is locked into the voltage of the other generators in the system. This presents another problem. The alternator with a slightly lower voltage set point will integrate its excitation setting to zero. The alternator with a slightly higher voltage set point will integrate its excitation setting open until it is carrying the entire system's kVAR load. The generators don't inherently share kVAR. To correct this situation the regulators are interconnected in a system called reactive cross current. This system tweaks the voltage regulator references using inputs from current transformers that are all connected together in series. Again, the weakness of this traditional approach is that it requires everything to work perfectly and unfortunately it tends to be sensitive to electrical noise.

Genset Control Protection

The fifth and sixth controllers are typically the genset controller and a protective relay. The genset controller is typically manufactured by the genset OEM and monitors various engine and alternator parameters and provides alarming per NFPA 110 requirements. The protective relay typically performs sync check, voltage and frequency, and reverse power functions. Companies like Beckwidth, Basler, Schweitzer, etc. typically manufacture protective relays. In addition to these controllers, the master control section includes a PLC from Allen Bradley, Modicon, Siemens, etc. This PLC is custom programmed for each project to coordinate relay logic between all the controllers in the system and provide basic communication and control for the system. The switchgear integrator programs the PLC.

Manual Control

As you can see, the traditional approach to paralleling generators does have its challenges. To enhance the reliability of these systems, switchgear is often wired with a manual mode of operation for when things go wrong. In this mode, the load share lines and cross current lines are opened and the control loops are typically placed in an inherently more stable control mode (droop). It should be noted that even in manual control mode, the generator still requires four mission critical controllers to function: governor, regulator, genset controller, and protective relay. Naturally, the question is — why so many controllers? Why not design the system with a single controller per generator?

THE INTEGRATED APPROACH TO PARALLELING

Integrated Digital Control

The first step in creating an integrated approach to generator paralleling is to utilize one digital controller per generator to control all generator functions: speed governing, voltage regulation, genset alarm and monitoring, synchronizing, load sharing, and protection. This consolidation of functions significantly changes the issues surrounding parallel generation. What was a complex system becomes a simple "plug and play" module. No more hardwiring multiple controllers together. No more difficult calibration processes. No more inherently unstable control loops. No more pulling I/O points back to the master PLC just to secure basic supervisor monitoring capabilities.

This approach of using a single digital controller per generator significantly enhances system performance. Inherently unstable load sharing methods are replaced with stable control loops. Synchronizing processes are greatly enhanced by directly interacting with frequency control functions. Troubleshooting becomes a simple process of monitoring inputs and outputs using a laptop computer. Repairs that took hours or days are reduced to minutes using an on-site spare controller and a simple plug and play approach. Supervisory control and monitoring is also made easy by simply passing all information digitally.

Beyond system performance, reliability is significantly enhanced. What was a maze of analog and digital controllers from different manufacturers hardwired together with complex interconnecting wiring is replaced with simplicity. Just the pure reduction in component count mathematically drives reliability through the roof. Furthermore, since all control functions are contained on a single CPU, this circuit board can be hardened from the effects of environmental degradation, mechanical stresses, and electrical interference.

The Integrated Paralleling Switch

The second step in creating an integrated approach to generator paralleling is to integrate the paralleling switch function into the generator connection box (figure 1), thus removing the cost and space of external switchgear. Once a generator becomes synchronized, the generator controller issues a close command to a paralleling switch that connects the unit to the generator bus. Historically this switch is a motor operated breaker located in a large metal cabinet, and connected to a bus bar. With an integrated paralleling system, the paralleling switch is a high cycle rated contactor specifically designed for switching power circuits, versus a breaker that is designed as an overcurrent protective device. The paralleling switch is mounted on and wired directly to the generator, resulting in a higher degree of system integration. The paralleling switch is then cabled to a common point that is typically a generator distribution panel (see figure 2). This cabling replaces the functionality of the generator bus bar inside traditional switchgear. From the generator distribution panel, various automatic transfer switches are fed. For single transfer switch applications, the wiring from the paralleling switches would be terminated directly to the transfer switch generator terminals. The end result of mounting the paralleling switch on the generator is a solution that features reduced complexity and cost while maintaining the benefits of a multiple unit system.

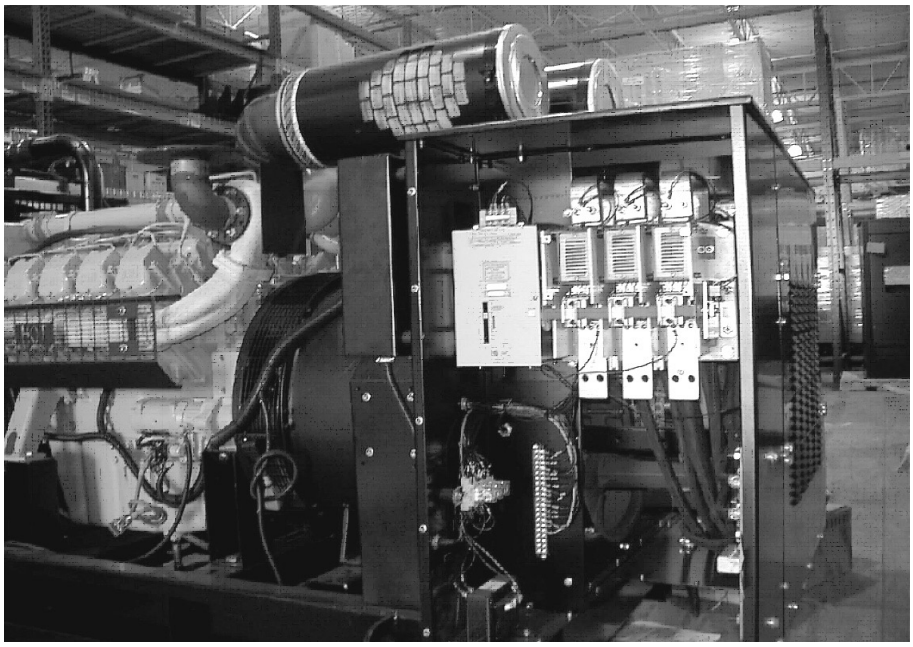


FIGURE 1
EXAMPLE OF A PARALLELING SWITCH MOUNTED ON A GENERATOR

SYSTEM MASTER CONTROL

Traditional switchgear utilizes a PLC to coordinate the operation of every generator and ATS in the emergency power system. An integrated paralleling system also needs a system controller for coordination. These functions include starting and stopping the generators, priority loading, load shedding and data collection for supervisory control by building management systems. A significant difference offered by an integrated approach is that most all communication to the system controller is digital versus the hardwiring required in many traditional systems. Also, the system controller does not have to perform relay logic to sequence multiple other controllers.

Operationally, each ATS monitors utility voltage and signals the system controller upon loss of utility supply. The system controller in turn communicates digitally to the integrated controller on each generator to control unit starting and stopping, along with sequencing for paralleling to the generator bus.

Operating Sequence

To understand the sequence of operation, let's look at an automatic start sequence initiated by a utility failure. For this example, Figure 2 shows an emergency power system with two generators and two automatic transfer switches (ATS's). The generators are connected to the system controller via a single RS485 data line. A two-wire start line is run from each ATS similar to any single engine standby solution, except the connection is made to the system controller. In this illustration the critical load ATS is configured to pick up load within ten seconds after a power outage. Upon utility failure, the transfer switches sense loss of utility power and provide a two-wire start signal to the system controller that provides a start command to all the generators in the system. The generators start and accelerate to rated speed. The system controller gives the first generator that reaches rated voltage and frequency permission to close onto the dead generator bus. Upon sensing the energized generator bus, the critical load ATS will transfer onto generator power. At this point, with one generator on the bus, the second ATS for equipment load is prevented from transferring onto the generator bus by a priority loading feature built into the system controller, thus preventing an overload of the first unit onto the generator bus. With the generator bus now energized, the remaining generator must synchronize to this power waveform before it can switch onto the bus for parallel operation. The integrated generator controller controls this process. As additional generators parallel to the bus, the system controller compares available generation capacity to expected load. Load is added in order of priority only when sufficient capacity is available. Another function of the system controller is load shedding. If a generator fails to start or fails during operation, load equal to the lost generator capacity remains offline or is removed from the system. Load shedding can be performed within the ATS or a shunt trip circuit breaker within the facility's distribution system.

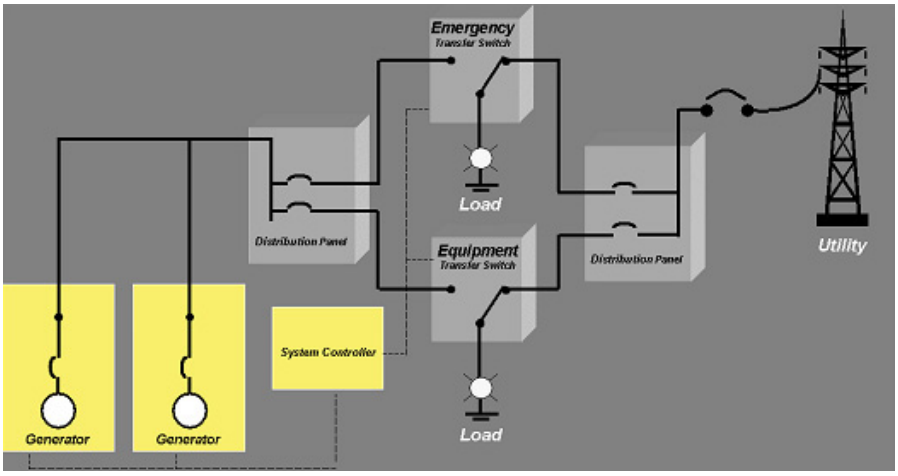


FIGURE 2
TYPICAL CONFIGURATION OF AN INTEGRATED PARALLELING SYSTEM

SUMMARY

The benefits of parallel generation are widely accepted in the marketplace; however, the implementation of these solutions has been limited. As mentioned, this is largely due to the constraints in implementing traditional paralleling solutions. These constraints include cost, space, issues of single source responsibility, and a significant level of complexity. To meet the market's expectations for price and performance, generator suppliers must migrate to an integrated digital control philosophy and relocate the paralleling switch function onto the generator. Through these steps, paralleled power solutions can be designed to compete cost effectively against single engine/generator price points while maintaining parallel generation benefits

Generac Power Systems
www.generac.com
1–888–GENERAC

NOTES

Online Final Assessment

Final assessments are available for each PDSS session. These assessments are Web-based and can be accessed using Generac's online learning system *"The Learning Center"* (http:// learning.generac.com). PDSS participants are required to obtain a score of at least 80% to pass an assessment. Each online assessment also contains a training survey. The survey provides each participant an opportunity to rate various components of the learning experience along with information relative to business development. Instructions for how to register and log in to this system, take the final assessment and print a certificate, are described in the Registering in *"The Learning Center"* section below.

Continuing Education

Upon successful completion of a seminar, participants will be awarded 2.0 PDHs (Professional Development Hours) and 0.2 CEUs (Continuing Education Units). Successful completion of a seminar requires that the participant have:

- Attended the complete seminar
- Received a minimum score of 80% on the Final Assessment

Certificate of Accomplishment

Participants who successfully complete the seminar and receive a passing score on the online final assessment are entitled to a "Certificate of Accomplishment." Certificates are available for printing directly from the participant's account screen on Generac's online training system *"The Learning Center".* Instructions for how to register and log in to this system, take the final assessment and print a certificate, are described beginning in the following section.

Registering in *"The Learning Center"*

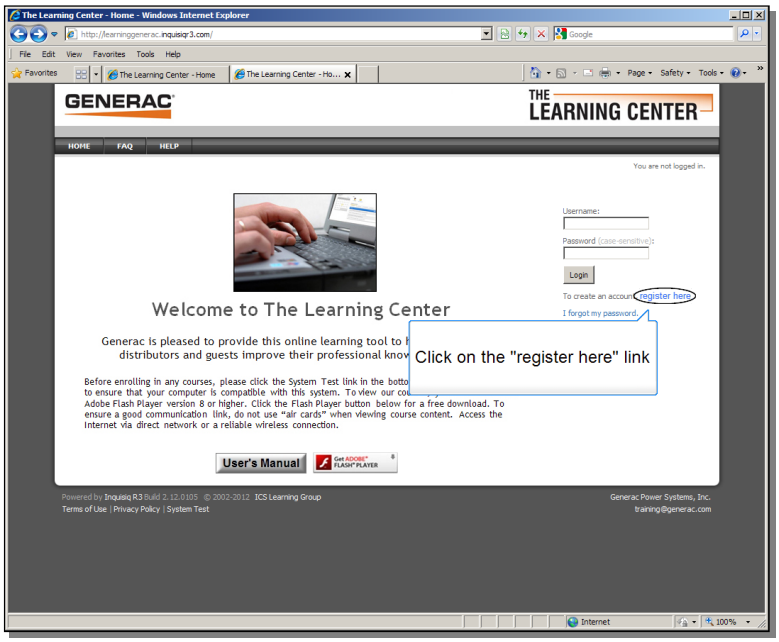
To gain access to *"The Learning Center*", you are required to register and set up a user account. During your account setup you will create a *Username* and *Password*. Your username and password can then be used to log in on subsequent visits.

The following pages will aid you in the registration process along with the Final Assessment, Survey and Certificate procedures.

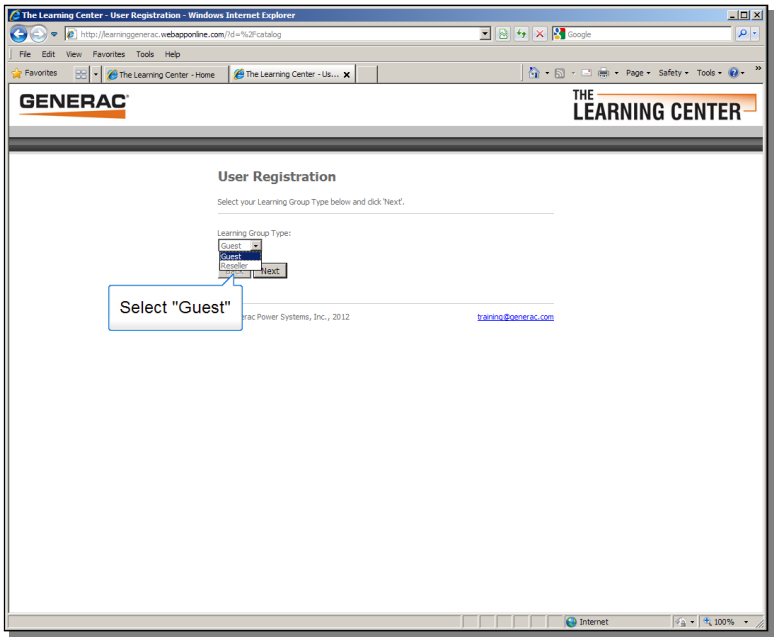
To begin the registration process, open your computer's browser and enter http:// learning.generac.com. This should take you to *"The Learning Center"* home page. This page is displayed at the top of the next page. From this point you can follow illustrated steps.

ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

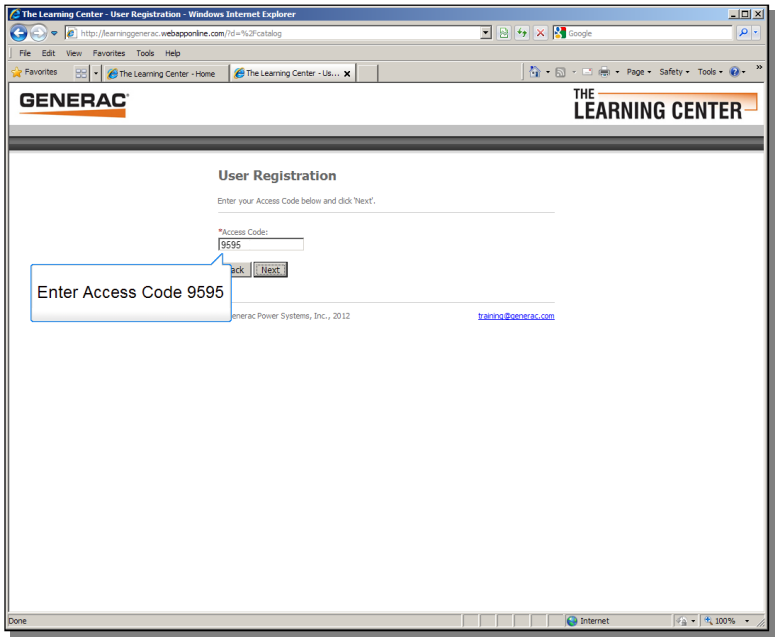
Begin by entering http://learning.generac.com in your computer's browser. The screen below will be displayed. Click on the "register here" link to begin the registration process.



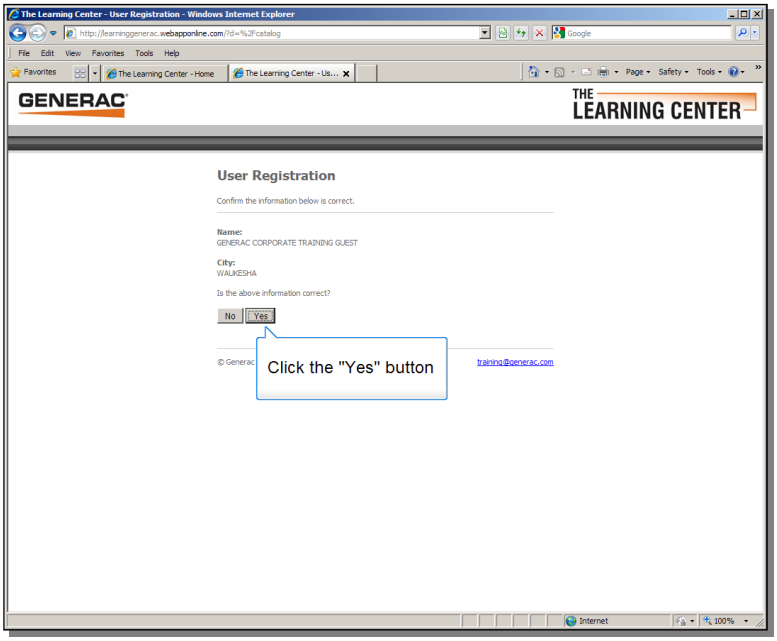
On this screen you will select "Guest" from the drop down box and click the "Next" button.



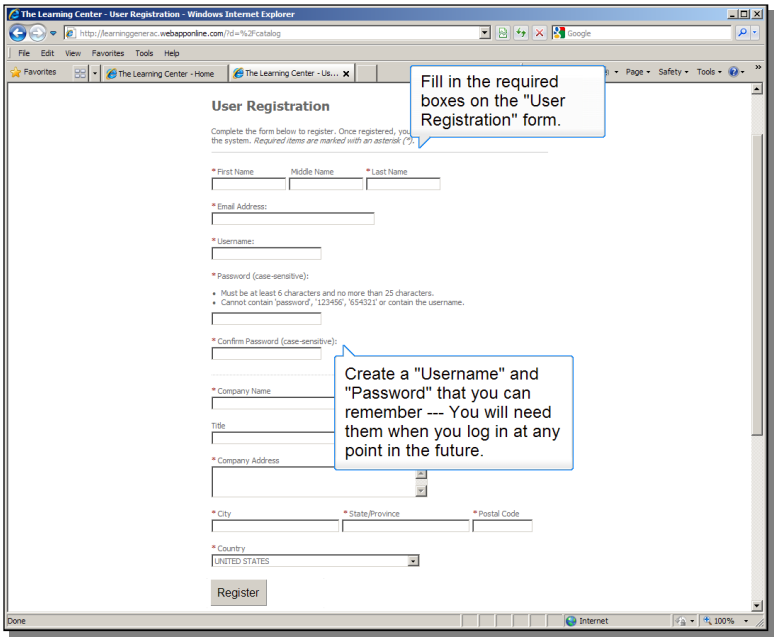
In this next screen enter **Access Code 9595** and click the “Next” button. Please keep this code private.



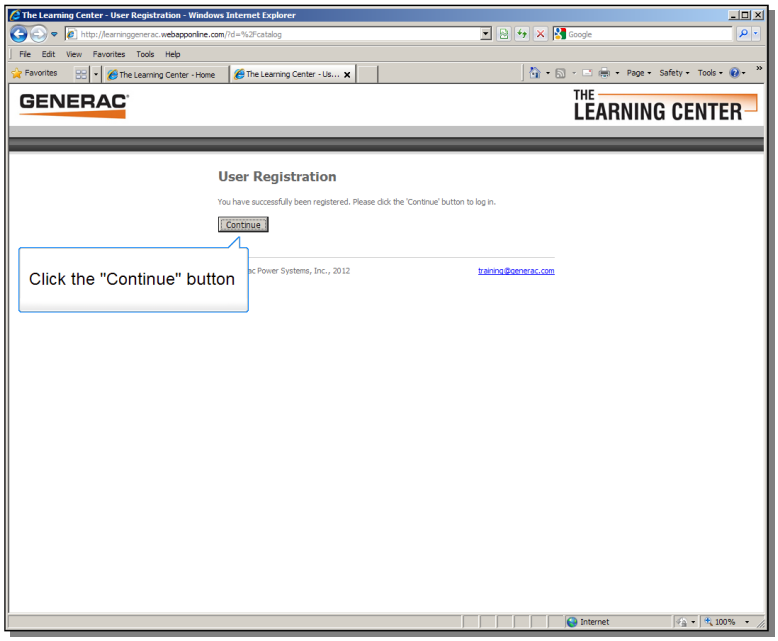
This screen confirms the correct access code entry. Click the “Yes” button to proceed.



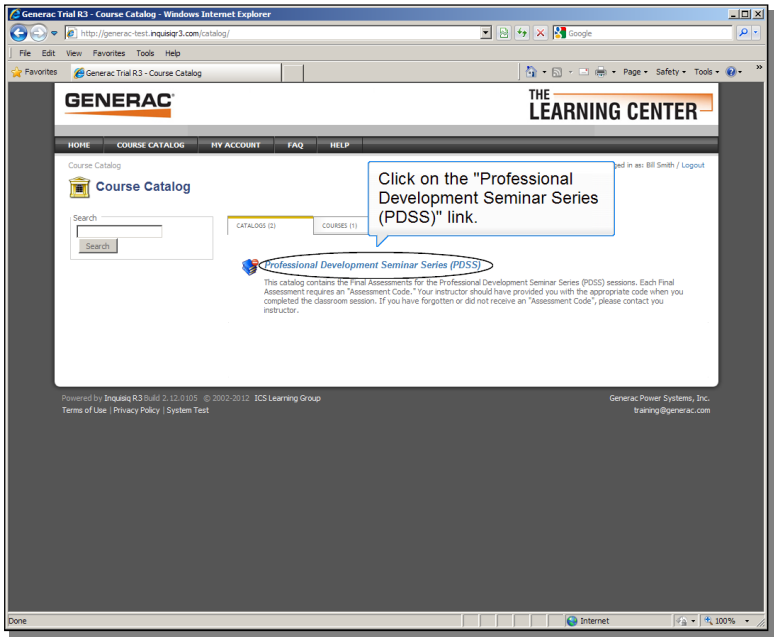
The next screen contains the “User Registration” form. Fill in the required boxes, and then click the “Register” button.



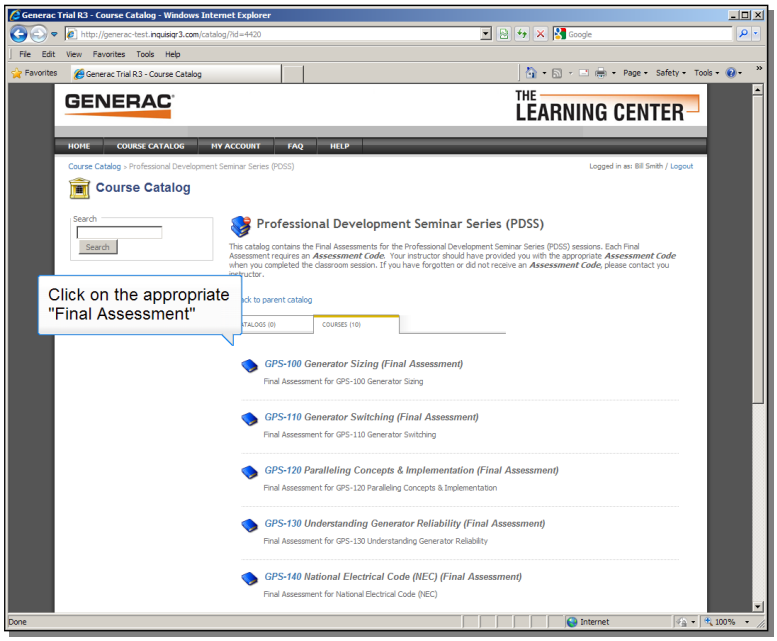
The next screen confirms your registration. Click the “Continue” button to proceed.



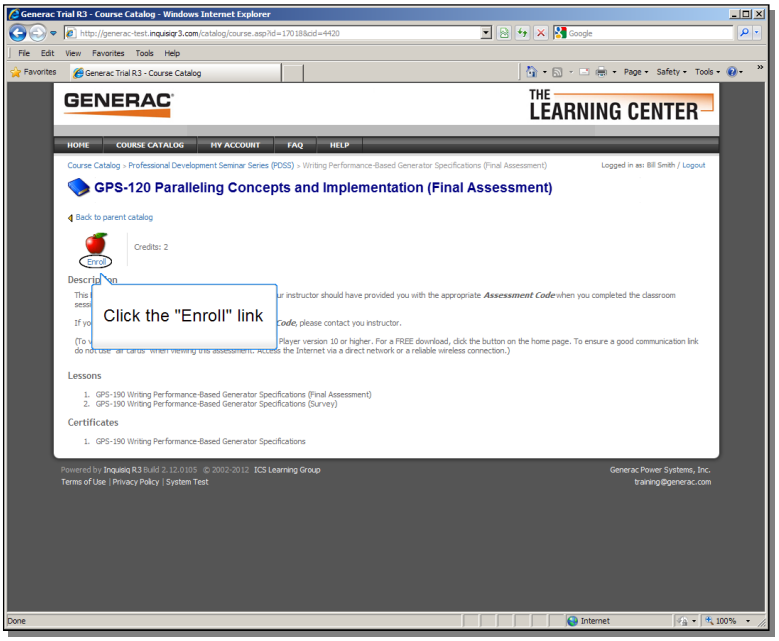
The next screen displays the “Course Catalog.” Click on the “Professional Development Seminar Series” link.



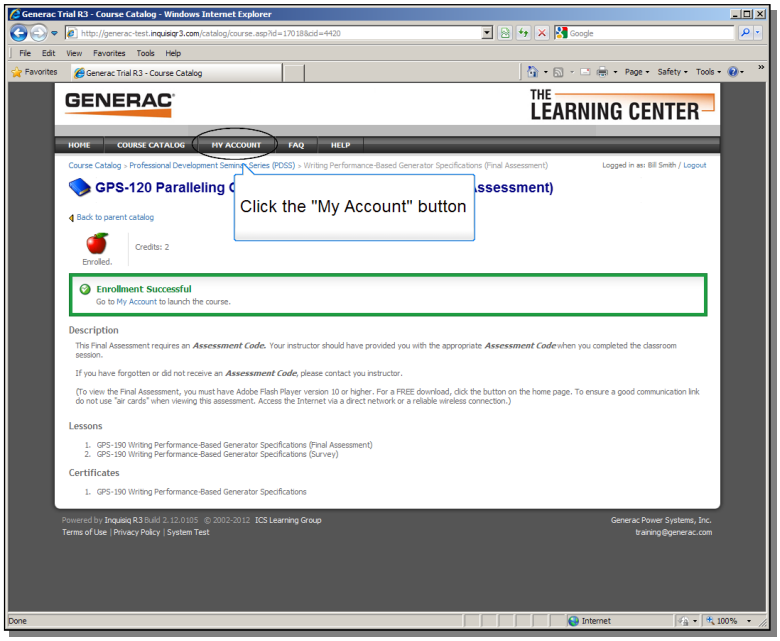
This next screen lists all currently available Final Assessments. Click on the Final Assessment that is tied to the course name and number you completed.



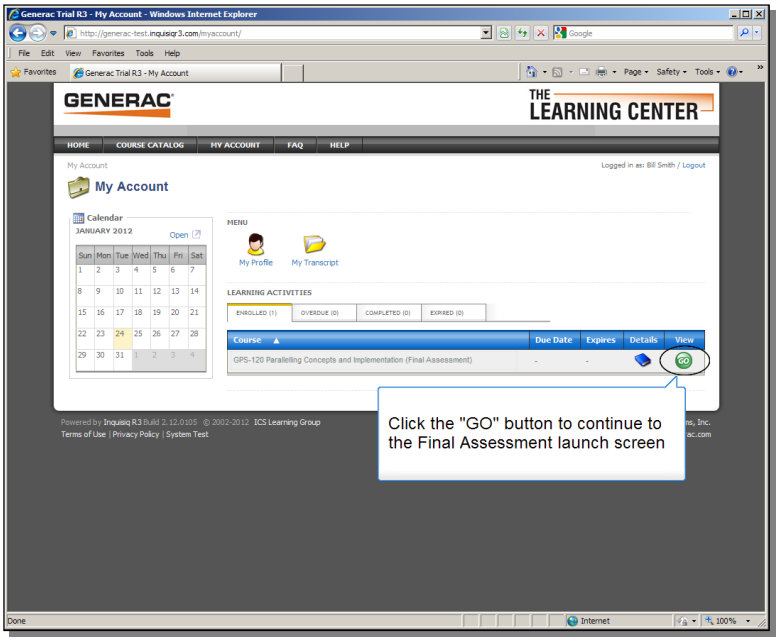
The next screen is the “Enrollment” screen for the Final Assessment that you selected. Click the “Enroll” link to proceed.



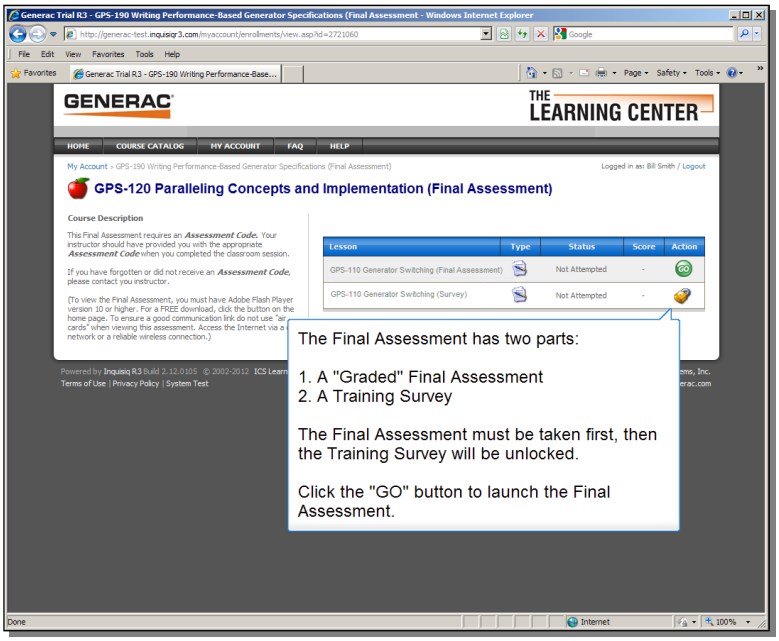
This screen confirms your enrollment. Click the “My Account” button to proceed.



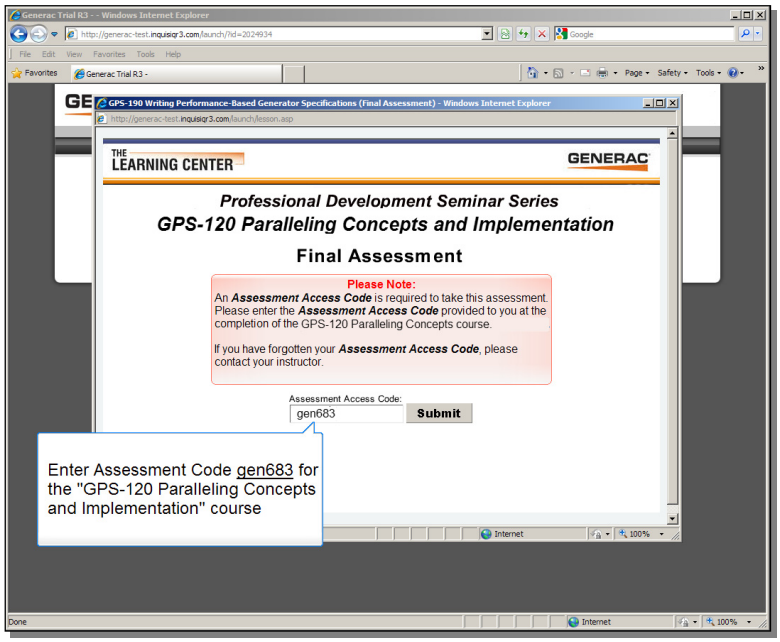
This is your “My Account” screen. Note that the Final Assessment you selected is displayed under the “Enrollment” tab. Click the “GO” button to proceed.



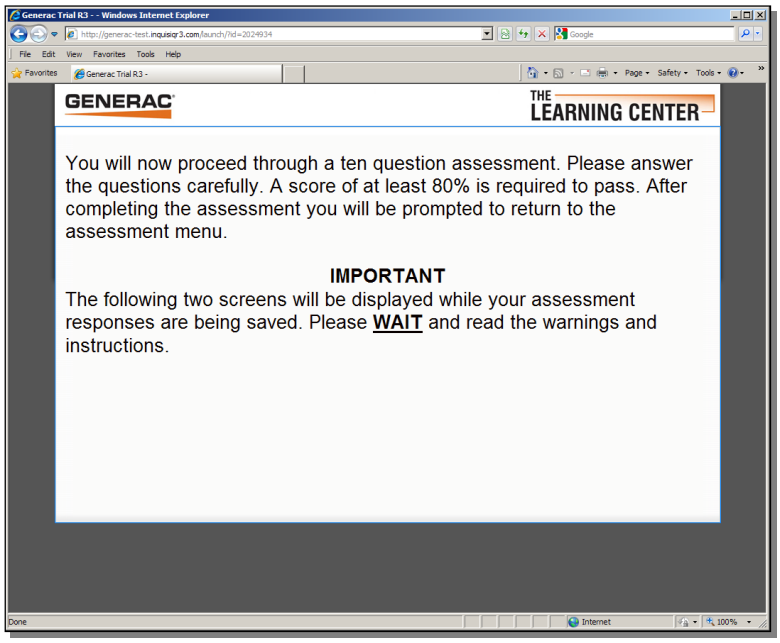
This screen lists the two parts to the Final Assessment. You must take the “Graded” Assessment first, then the Training Survey.



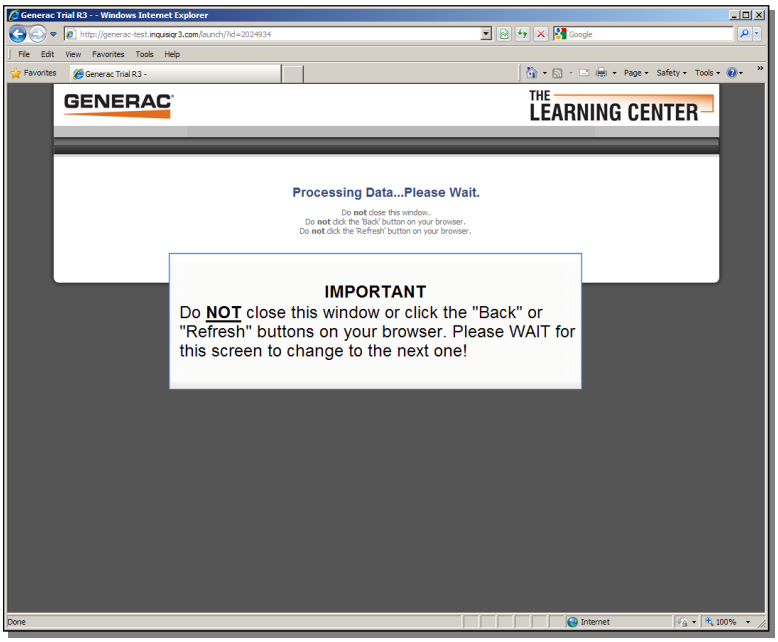
In the next screen an “Assessment Code” is required before you can continue. The code for GPS-120 Paralleling Concepts and Implementation is **gen683**. Enter the code in the box and click the “Submit” button to continue.



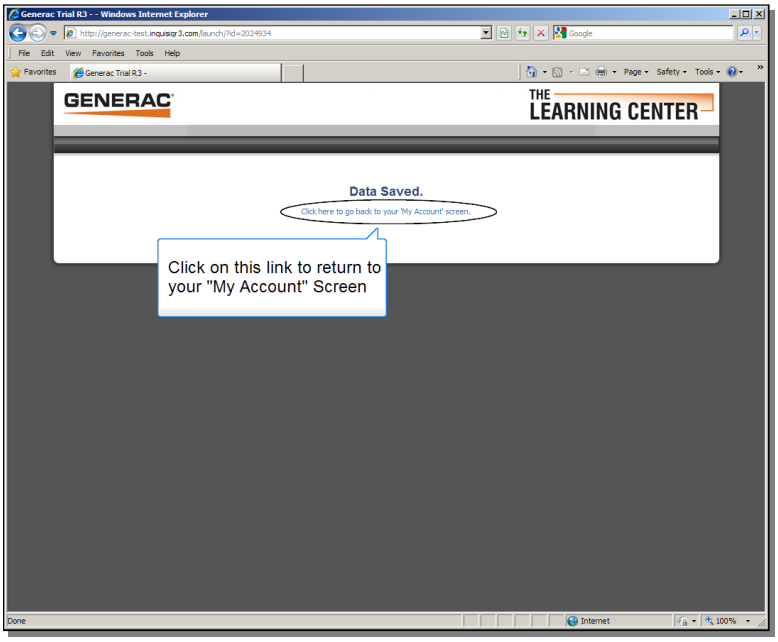
You will now proceed through a ten question assessment. Please read the warnings below.



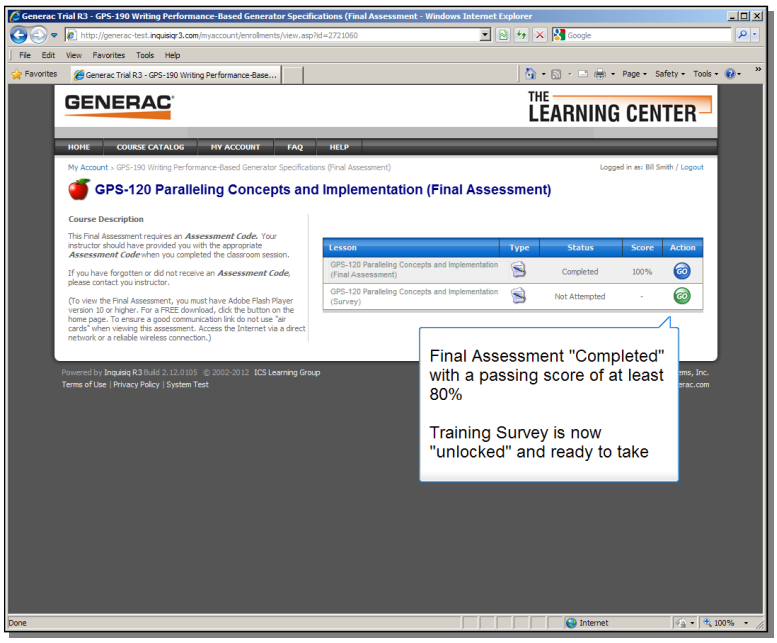
Please follow the instructions on this screen. You must wait for your assessment data to be saved. Do not close this window or click the 'Back' of 'Refresh' buttons on your browser.



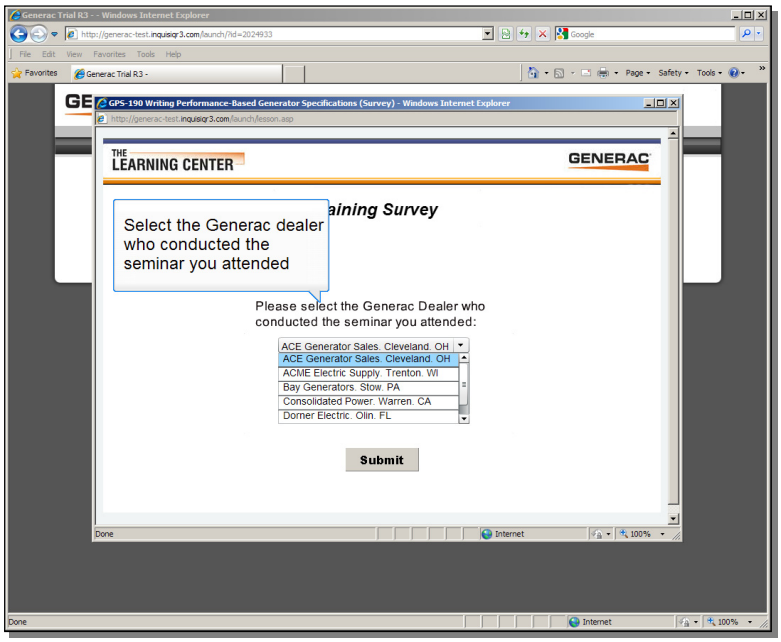
This screen confirms that your data was saved. Click on the link shown here to proceed.



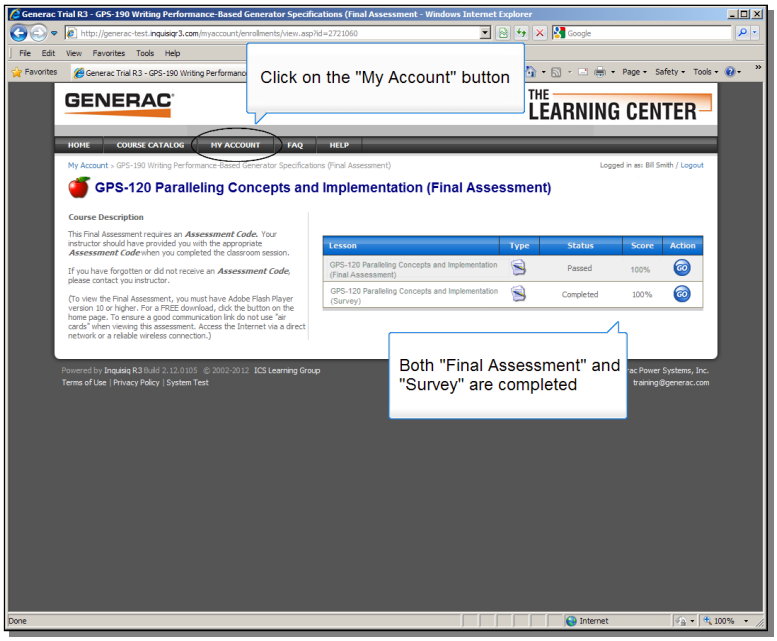
This screen will be displayed after your assessment data is saved. Note that in this example the assessment was passed with a score of 100% and the Survey is unlocked and ready to launch.



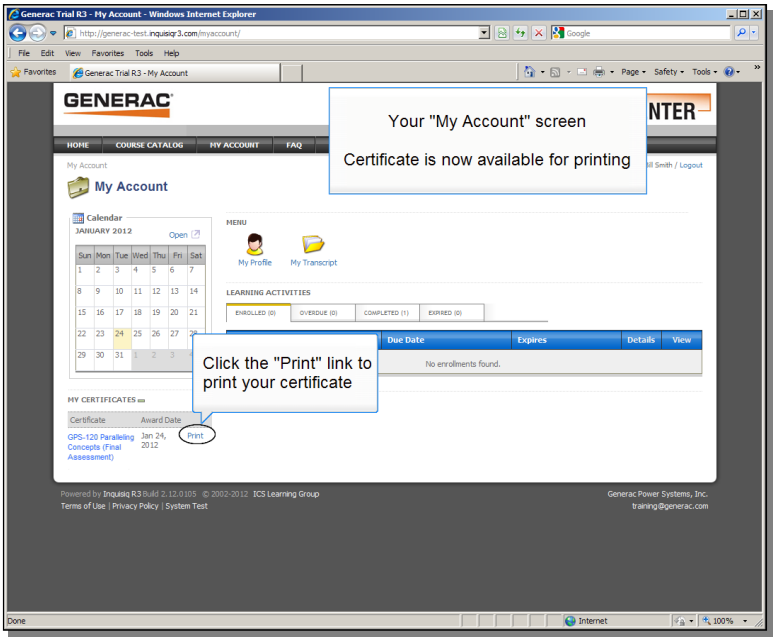
Upon launching the Survey, this screen will be displayed. Select the Generac dealer who conducted the seminar you attended.



After completing the survey you will be prompted to return to the assessment menu. Your response data will be saved as before, and you will see the screen below. Click the “My Account” button to continue.



Your “My Account” screen will look similar to the one shown here. Click the “Print” link to print your certificate.



NOTES

NOTES

GENERAC®
INDUSTRIAL POWER

Generac Power Systems, Inc.
S45 W29290 Hwy. 59
Waukesha, WI 53189
1-888-GENERAC (1-888-436-3722)

generac.com

Part No. GPS1205000 rev. D / Printed in USA 02/02/12