PROFESSIONAL DEVELOPMENT SEMINAR SERIES

GPS-300
Generator Sizing (Part 1)

LEARNER'S GUIDE

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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 control systems are 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, have 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 incorporates proven learning methodology to ensure a positive experience. These modules are designed to broaden the learner's understanding of topics such as:

- Sizing
- Switching
- Paralleling
- Reliable Design
- NEC Requirements
- NFPA Standards
- Engines & Alternators
- Controls
- Emissions
- Spec Writing
- Fuel Choices
- Gas Piping Design

THE MODULE IN PERSPECTIVE

PURPOSE

When it comes to generator sizing, the discussion can focus on an entire facility or on a specific type of concentrated load. This module will focus on sizing whole buildings, the NEC sizing requirements, impacts of starting motors, and importance of natural load sequencing to generator sizing. Part two of the sizing discussion is covered in GPS-305 and focuses on isolating loads onto a generator where the unique characteristics of the load become very important.

TIME:

- 45 minutes of classroom instruction
- 15 minutes for final assessment

LEARNING OBJECTIVES:

Upon completion of this module, participants will be able to:

- Explain how to use measurement and billing history data to size a generator
- Descibe the NEC requirements for generator sizing
- Understand the impact that load sequencing has on generator size
- Quantify the impacts of starting motors across the line on generator sizing
- Explain the difference between instantaneous voltage dip and 90% sustained

CONTINUING EDUCATION:

Upon successful completion of this seminar, participants will be awarded a certificate of achievement identifying the seminar title, 1.0 PDHs (Professional Development Hours) and .1 CEUs (Continuing Education Units).

Successful completion of a PDSS seminar requires that the participant have:

- Attended the complete seminar
- A minimum score of 80% on the final assessment

GPS-300 Generator Sizing (Part 1)

Presented by Generac Industrial Power

PROFESSIONAL DEVELOPMENT SEMINAR SERIES

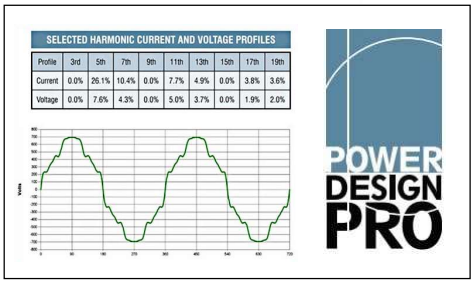
Agenda

- **Agenda**
  - Approaches to generator sizing
    - NEC sizing
    - Measurement
    - Sizing programs
  - New construction challenges
    - Load level & load type uncertainty
    - Load growth
  - Unexpected surprises
    - Leading power factor
    - Motor starting transients
    - Competitive discussion - meaning of “90% sustained”
    - Load sequencing

POWER DESIGN PRO™

Approaches

- **Approaches to Generator Sizing**
  - NEC requirements
    - Various load types have different code requirements
  - Engineering judgement
    - New construction
    - Rules of thumb (kW/ft^3)
  - Measurement data
    - Existing facilities
  - Generator sizing programs (Power Design Pro)
    - Analyze transients (voltage & frequency dips)
    - Analyze harmonics



*Source: FLUKE Corporation

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Approaches to Sizing

NEC Sizing

Measurement Data

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NEC Sizing

- **Emergency Power Systems (NEC 2017)***
  - NEC 700.4(A) (Emergency System - Capacity)
    - "…adequate capacity and rating for **all loads to be operated simultaneously**"

- **Emergency Power Systems (NEC 2020)***
  - NEC 700.4 (Emergency System - Capacity)
    - "…adequate capacity in accordance with **article 220 or by another approved method**.

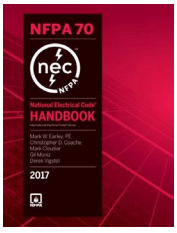
  - NEC 517.31 D (Health Care Facilities)
    - "… to meet the maximum **actual demand likely to be produced**…"
      "**NEC 700.4 & NEC 701.4 shall not be applied to hospitals**"
    - Practical sizing based on historical, demand factors, calculations

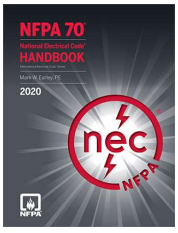
*Source: National Fire Protection Association (NFPA.org)

NEC Sizing

- **Standby Power Systems (NEC 2017)***
  - NEC 701.4 (Legally Required System - Capacity)
    - "…adequate capacity and rating for **all loads intended to be operated at one time**"

- **Standby Power Systems (NEC 2020)***
  - NEC 701.4 & 702.4(B)(2) (Legally Required & Optional - Capacity)
    - "…adequate capacity in accordance with **article 220 or by another approved method**.

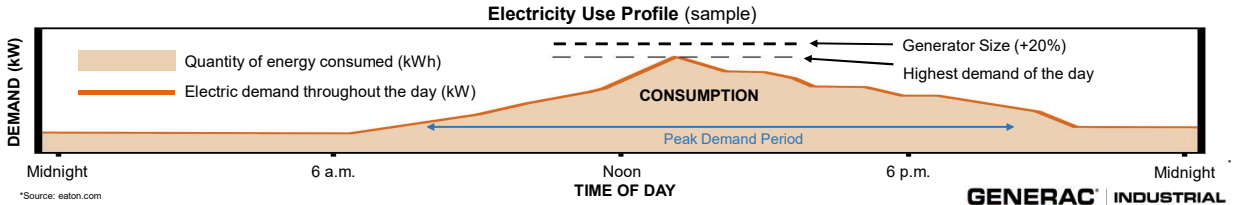




*Source: National Fire Protection Association (NFPA.org)

NEC Sizing

- **Article 220 (Feeder & Service load Calculations`**
  - Part III
    - Sum of the loads on the branch circuits
    - Applicable code allowed demand factors
    - Non-coincidental load allowance
  - Part IV
    - Existing installations can use actual maximum demand
      - Utility peak demand info across one year
      - Measurement data: 30 days
    - Generator sized for 80% loading (demand x 1.25)



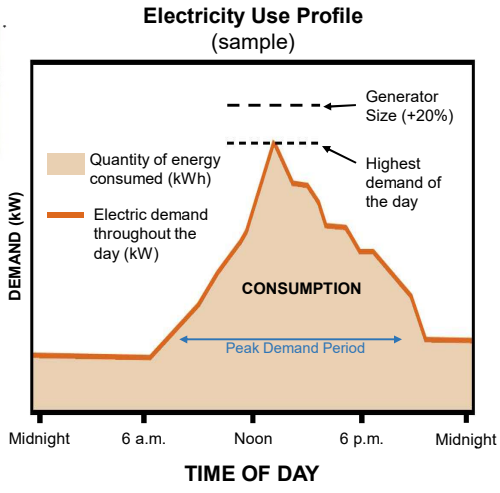
*Source: eaton.com

Measurement Data

- **Existing Facilities Should Utilize Historical & Measurement Data**

- **Billing History**
  - Demand charges (capture peak kW)
    - Captures seasonality & business cycles
    - Peak power over 15 minute average
      - Does not include motor start transients

- **Power Analyzer**
  - Snapshot / short history (measures transient spikes)
  - NEC wants 30 days (15 min averages)
  - Capture power quality
    - Harmonic content
    - Power factor



*Source: FLUKE Corporation

Other Approved Methods

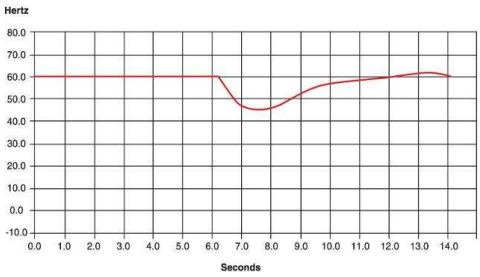
- **“Other Approved Methods”**
  - Open to AHJ interpretation
  - AHJ & plan review have to be comfortable with the sizing process
  - Engineering judgement & PE stamp carry weight
    - New construction circuit loading may be under defined
    - Historical design rules for needed (kW/ft^3)
    - Factors for uncertainty & load growth

*Source: Computerhistory.org

Matching Load Characteristics to the Generators

- **Sizing Larger Applications (many mixed load types)**
  - No single load is all that important
    - Add up total kW
    - Identify the largest transient load (typically an across the line starting motor)
    - Verify that harmonics aren't an issue (covered in Generator Sizing (Part 2))

- **Isolating Loads & Smaller Applications (covered in Generator Sizing (Part 2))**
  - Characteristics of the load is important
    - Accurate modeling of the load characteristics is important
    - Transients (starting kVA & starting kW)
    - Harmonics
  - Characteristics of the Genset are important
    - Voltage stiffness
    - Volts / Hertz response (large natural gas units – softer frequency)
    - Alternator reactance
    - Peak kW capability



Generator Sizing Programs

- **What Generator Sizing Programs Do Well**
  - Analyze a few discrete loads
  - Analyze a transient load with given pre-load (like a motor start)
  - Harmonics analysis (Generac Power Design Pro unique)
  - Mechanical design (gas piping, exhaust piping, layout)
  - www.powerdesignpro.com

- **Can Generator Sizing Programs Accurately Size Buildings?**
  - No, why:
    - Entering a complete load list assumes all loads are energized
      - Load diversity factors aren't modeled
    - Entering too many loads in a single load step creates a "false" condition
      - Most loads sequence naturally with limited concurrent starting

*Source: electricmotorsforless.com

**Source: illinoiscss.org

Natural Load Sequencing

- **Concurrent or Non-concurrent Load Sequencing Assumptions**
  - When power fails all the loads power-off
  - When ATS transfers load is minimum (typically connected lighting)
  - Most loads naturally sequence back-on
    - Chillers & compressors must bled off head pressure
    - UPS have a timer for utility good
    - Machines must be restarted
    - Simple control relay can prevent concurrent starting

- **Generac's Power Design Pro (available online)**
  - Supports both concurrent & non-concurrent
  - Recommend using "Group" – assumes non-concurrent load start with largest last
  - Program also includes "Steps" – for few times when loads must start concurrently

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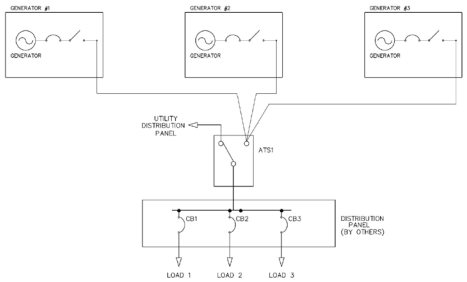
*Source: Trane.com

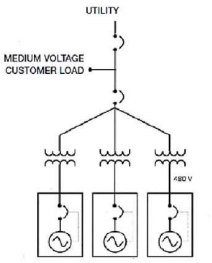
Load Uncertainty – New Construction

- **New Construction Should Be Sized Using Engineering Judgment**
  - What is the anticipated load level
    - Often services are sized conservatively (actual loads of 50% are not uncommon)
    - Typically, the generator is sized less robust than the service
  - What circuits are going to be connected?
    - Whole building, selected standby loads, emergency system
    - End users often want a large load list initially
    - What loads are essential & what are optional?
  - What types of loads will be connected?
    - Resistive (kW)
    - Motor Loads (transients & voltage dips)
    - Non-Linear (voltage distortion)

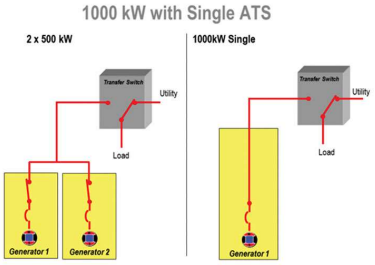


Load Uncertainty – Load Growth

- **What Is The Expected Load Growth?**
  - Does the end user have an aggressive growth plan?
  - How certain is the business model?
  - What is the value of different capital expenditures?



- **Would The Customer Benefit From An Expandable Solution?**
  - Is integrated parallel generation an option?



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Load Uncertainty – Transient Loads

- **What Are The Largest Load Steps On The Generator?**
  - Starting large motor loads can challenge system sizing

- **What Are The Acceptable Transient Limits?**
  - Generators are not infinite sources
  - Expect voltage & frequency dips
  - Size for total power and transient performance
    - Size based upon largest load step while powering the building
    - For general (non-dedicated) loads, limit the voltage dip to 15%
    - Frequency dip seems to be less of an issue (most loads don't care)

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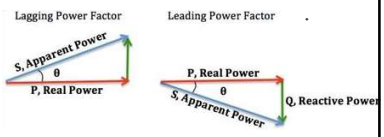
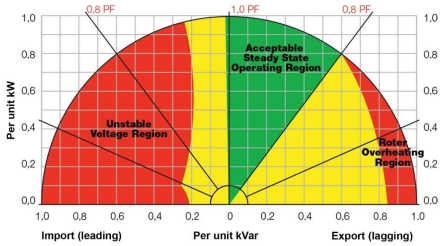
Load Uncertainty – Leading PF

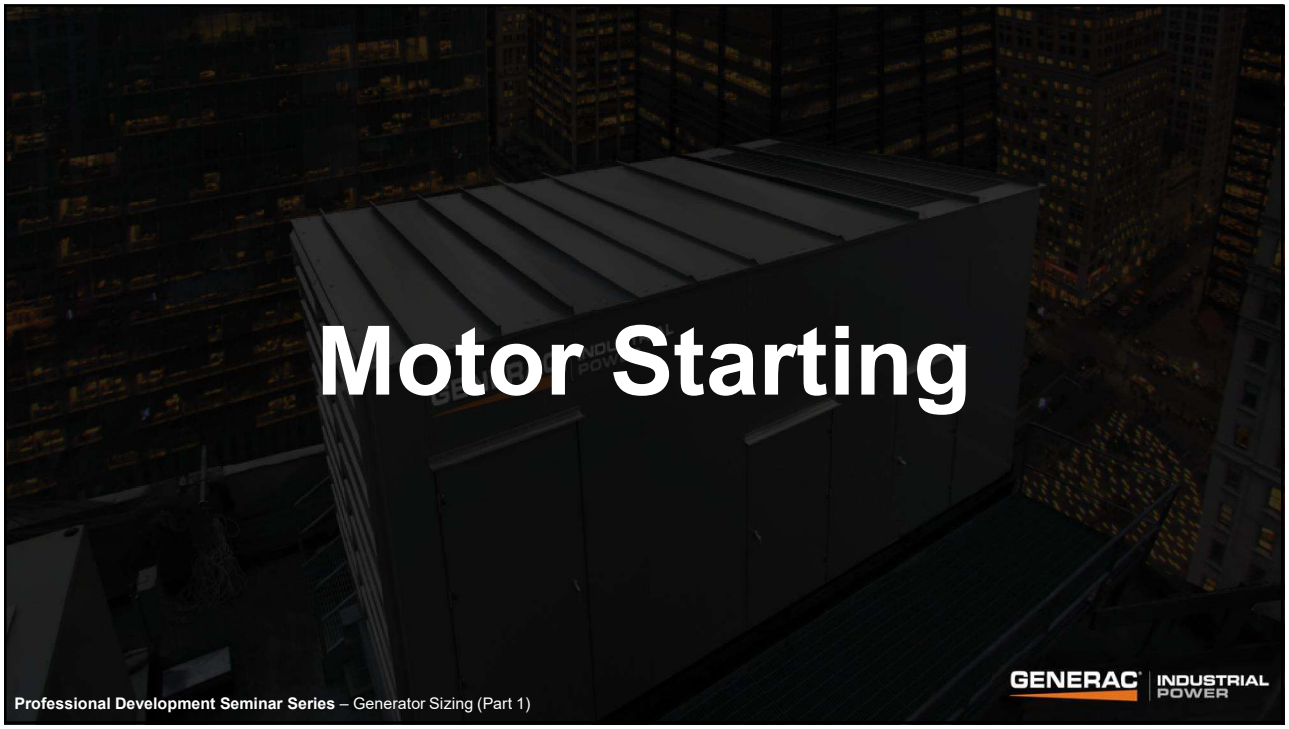
- **Generators Are Rated For .8 PF (Lagging) To 1.0 PF**
- **Leading PF Can Cause Self Excitation Resulting In**
  - Voltage instability
  - Over-voltage shutdowns
- **Sources Of Leading Power Factor**
  - Power factor correction capacitors at the service
  - Lightly loaded (less than 30%) UPS's & VFD's with filtering
    - Capacitor cut-out contactor filter option
- **If Power Factor Is Leading**
  - Remove the leading power factor elements
  - Add offsetting lagging power factor loads



Steady state alternator reactive power capability curve



*Source: billfinnell.com
**Source: electricalknowledgecommunity.blogspot.com

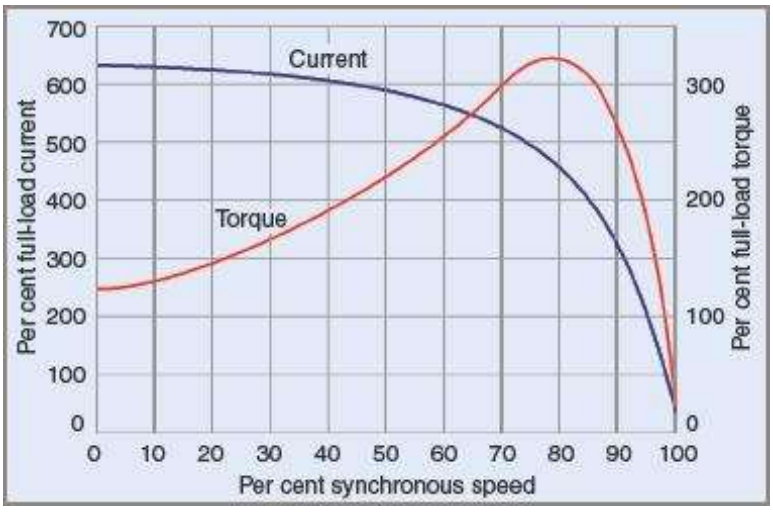


Motor Starting Transients

Engine
- Starting kW
- Frequency dip

Alternator
- Starting kVA
- Voltage dip

Motor Starting Transients (Starting kVA)



*Graph Source: electricala2z.com

Motor Starting Transients (Starting kVA)

- **What Happens When A Contactor Closes To Start An Electric Motor?**
  - Immediate inrush of current
  - Inrush is referenced as:
    - Locked rotor amps (LRA)
    - Inrush current or motor starting current
  - Converting LRA to skVA
    - skVA easier for using rules

$$skVA = \frac{V_{LL} * I_{LR} * \sqrt{3}}{1000}$$

$$623 = \frac{480 * 750 * \sqrt{3}}{1000}$$

skVA required to start the motor

Note: "s" indicates the motors starting period

Motor Starting Transients (Starting kVA)

- **Starting Codes**
  - Determines skVA
  - NEMA standard
    - Always check motor plate for NEMA Code or LRA
- **Example:**
  - 100hp x 6.0 skVA/hp = 600 skVA
    (Code G Motor)
  - Typical motor is 6.0 skVA/hp

Letter Designation	kVA per hp
A	0 – 3.15
B	3.15 – 3.55
C	3.55 – 4.0
D	4.0 – 4.5
E	4.5 – 5.0
F	5.0 – 5.6
G	***5.6 – 6.3***
H	6.3 – 7.1
J	7.1 – 8.0
K	8.0 – 9.0
L	9.0 – 10.0
M	10.0 – 11.2
N	11.2 – 12.5
P	12.5 – 14.0
R	14.0 – 16.0
S	16.0 – 18.0
T	18.0 – 20.0
U	20.0 – 22.4
V	22.4 and up

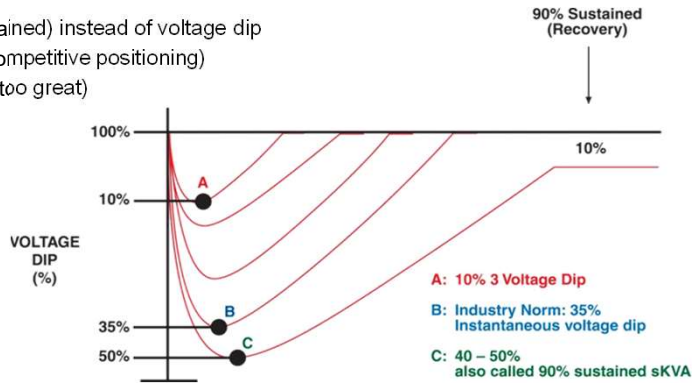
Professional Development Seminar Series – Generator Sizing (Part 1)

Motor Starting Transients (Starting kVA)

- **Expected skVA**
  - Name plate data
    - Typically have a NEMA starting code
    - Don't confuse design codes (B,C,D) & starting codes (expect code F or higher)
    - LRA (locked rotor amps)
  - IEC vs. NEMA
    - European motors (IEC) typically have higher starting currents
  - High efficiency
    - High efficiency motors have higher starting currents

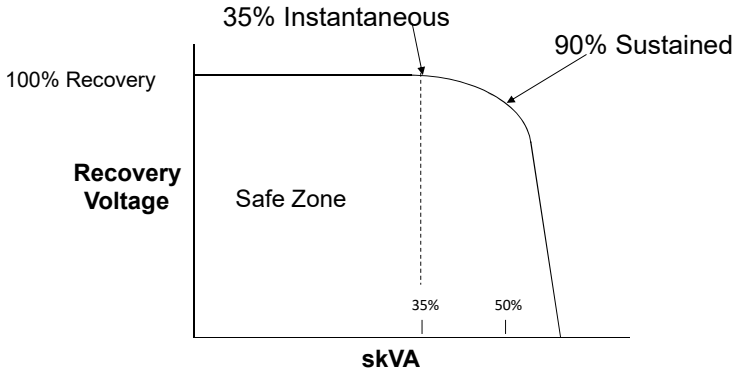
Motor Starting Transients (Alternator Response)

- **Each Line Is The Response For Successively Larger Motors**
  - Line B represents the industry suggested maximum alternator capability limit (35% Vdip) (limit of NEMA motor starter)
  - Line C is used by one OEM
    - Focuses on recovery voltage (90% sustained) instead of voltage dip
    - Generates a very large skVA number (competitive positioning)
    - No application relevance (voltage dip is too great)



Motor Starting Transients (Alternator Response)

- **Operating Beyond 35% Voltage Dips**
  - Typically results in collapsing the alternator output voltage
  - Often resulting in application issues (motor contactors dropping out)



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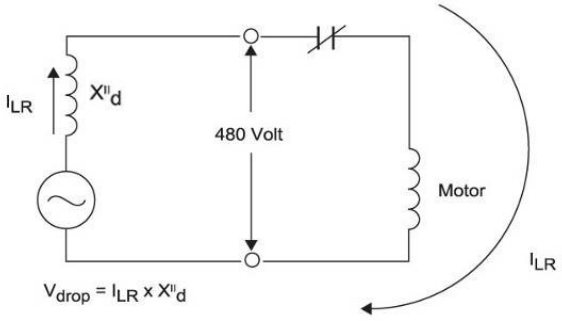
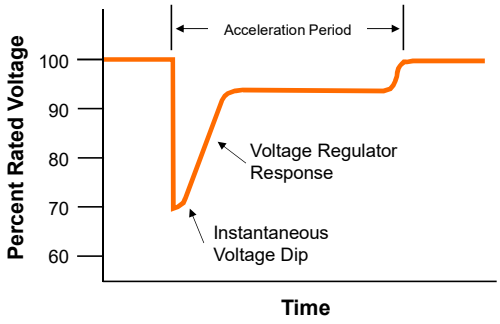
Motor Starting Transients (Alternator Response)

- **Why does the alternator voltage dip?**
  - Ohm's law : V = IR





- **How do we minimize the voltage dip?**

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Motor Starting Transients (Alternator Response)

- **Improve Motor Starting**
  - Minimize X "$_d$ (generator sub-transient reactance)

Upsizing the Alternator (improves motor starting)

Example: 50hp x 6.0 skVA/Hp = 300 skVA

Voltage dip	35%	25%	20%	15%	10%
Alternator	130	200	250	300	600

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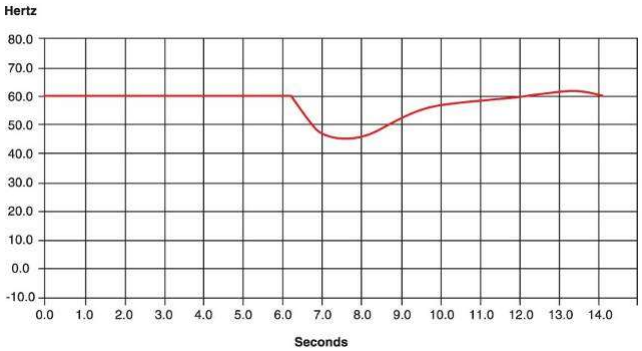
Motor Starting Transients (Engine Response)

- **How Does The Engine Respond To Motor Starting?**
  - Frequency dips are dependent on engine configuration & voltage regulator unloading
    - Fuel type (diesel vs. natural gas)
    - Engine displacement
    - Engine technology (mechanical vs. electronic injection)



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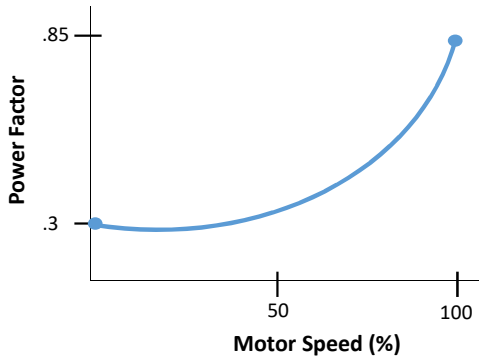
Motor Starting Transients (Engine Response)

- **Why does the engine speed dip during a motor start?**
  - PF = kW/kVA (definition of PF)
  - sPF = skW/skVA (add "s" for starting period)
    - Function of motor size & design
    - Typical sPF range is .25 to .45 (1000 to 5hp)
    - Power factor increases when motor accelerates
  - skW = skVA x sPF (calculate for starting kW)
  - Example of skW (Start kW)
    - 100 hp x 6.0 (skVA/hp) = 600 skVA
    - 600 skVA x .3 sPF = 180 skW



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Motor Starting Transients (Engine Response)

- **Engine Speed (Frequency)**
  - Frequency will dip
  - skW ≅ 2 x motor hp (conservative estimate for across line starting)
- **Engine Performance**
  - 8 to 12 hertz dip @ 100% load step (average diesel performance)
  - 12 to 18 hertz dip @ 100% load step (average gas performance)
  - Frequency dip is managed by the regulator volts-per-hertz function
    - Shedding voltage reduces the load seen at the engine by a square function (Power = V^2/R)
- **Load Acceptance**
  - Most loads are tolerant of frequency dips
  - Line interactive UPS technologies are frequency sensitive

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Motor Starting Transients (Rule of Thumb)

- **Rules of Thumbs**
  - Alternator
    - skVA = hp x 6.0
    - rkVA = hp
  - Engine
    - skW = hp x 2
    - rkW = hp x .85

EXCEPTIONS: SPECIALTY MOTORS

Submersible Pumps
skVA = hp x (12 to 14)

Motor Starting Transients (Exercise)

- **Three Motors Are At A Pump Station**
  - 50hp, 100hp, 200hp
- **What sequencing should we assume?**
  - What order gives us the smallest generator?
  - What sequencing typically matches the real world application?
  - Exercise 1 (start sequence 200hp, 100hp, 50hp) – Largest first
  - Exercise 2 (start sequence 50hp, 100hp, 200hp) – Largest last
  - Exercise 3 (start all the motors simultaneously)

Notes the following slides:
"s" indicates starting
"r" indicates running
"p" indicates peak (previous running loads with current starting loads)

Motor Starting Transients (Exercise)

Example 1: Start sequence – 200hp 1st, 100hp 2nd, 50hp 3rd

Start 200hp x 2 = 400 skW (need 400 kW genset minimum)

Run 200hp x .85 = 170 rkW (preload for next load step)

Start 100hp x 2 = 200 skW + 170 rkW = 370 pkW (400 kW genset is still enough)

Run 300hp total x .85 = 255 rkW (preload for next step)

Start 50hp x 2 = 100 skW + 255 rkW = 355 pkW (400 kW engine)

Recommended Size 400 kW

To determine alternator size for voltage dip
assume skVA = 6 x hp = 6 x 200hp = 1200 skVA

To determine voltage dip, use alternator data sheets

Motor Starting Transients (Exercise)

Example 2 Start sequence – 50hp 1st, 100hp 2nd, 200hp 3rd

Preload of (100 + 50)hp x .85 = 127 rkW

Start 200hp x 2 = 400 skW + 127 rkW = 527 pkW

Recommended Size 500-600 kW

Motor Starting Transients (Exercise)

Example 3 Start sequence - all three instantaneously

Start (200 + 100 + 50)hp x 2 = 700 skW

Recommended Size 700 kW

Load sequence impacts generator sizing!!

We recommend using "Groups" in Power Design Pro
Assumes natural sequencing with largest load coming on last

Sizing Summary

- **Existing facilities**
  - Use measurement and billing history demand charge information
  - Consider the building load as pre-load & model starting biggest motor
- **New construction**
  - Engineering judgement & design rules
  - Scalable solutions are a valuable tool to deal with uncertainty and load growth needs
- **Leading Power Factor**
  - Turn off power factor correction or add other offsetting lagging loads
- **Motor Starting**
  - skVA is typically Hp x 6 (this is the impact on the alternator – used for calculating voltage dip)
  - skW is typically Hp x 2 (this is the impact on the engine – used for peak loading and frequency dip)
  - Typically assume natural motor sequencing (non-concurrent starting) with largest coming on last
  - Limit whole building applications to 15% voltage dip
  - Limit simple NEMA motor starter applications to 25-35% voltage dip
  - "90% sustained" is a marketing gimmick by one OEM and has no application relevance

ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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 this seminar, participants will be awarded 1.0 PDHs (Professional Development Hours) and 0.1 CEUs (Continuing Education Units). Successful completion of a seminar requires that the participant have:

- Attended a 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":

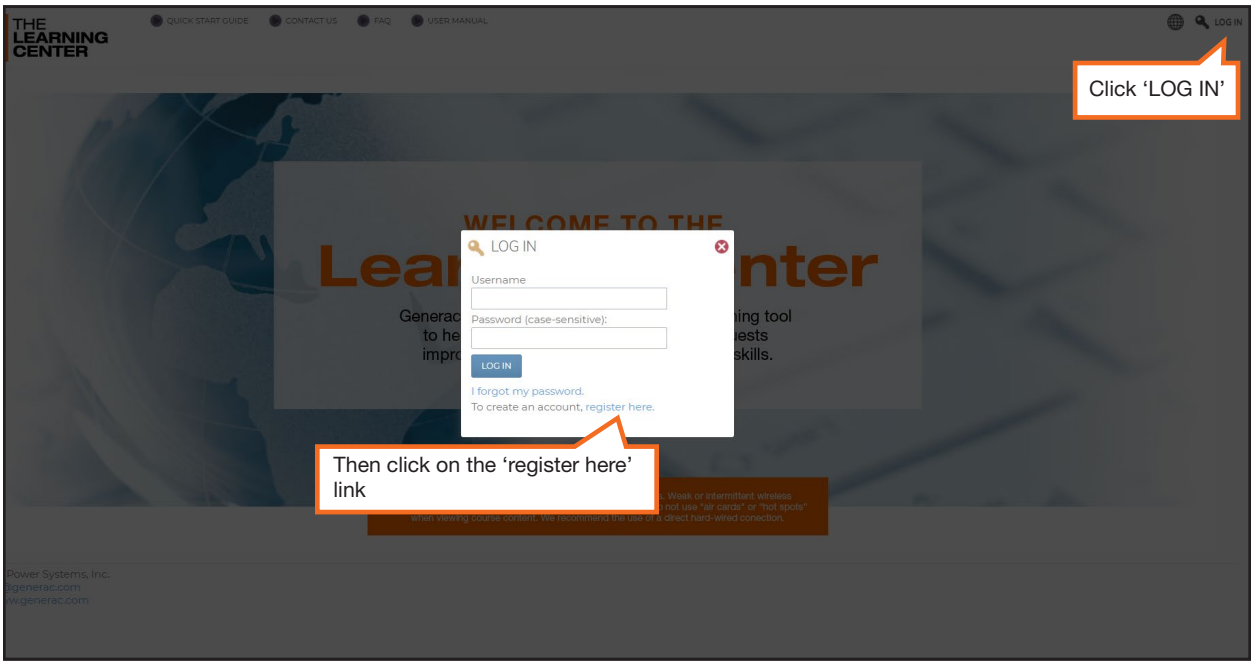
To gain access to "The Learning Center", you are required to register and set up a user account. During your account setup you will create a username and password. Your username and password can then be used to log in on subsequent visits.

The following pages will aid you in the registration process along with the final assessment, survey and certificate procedures.

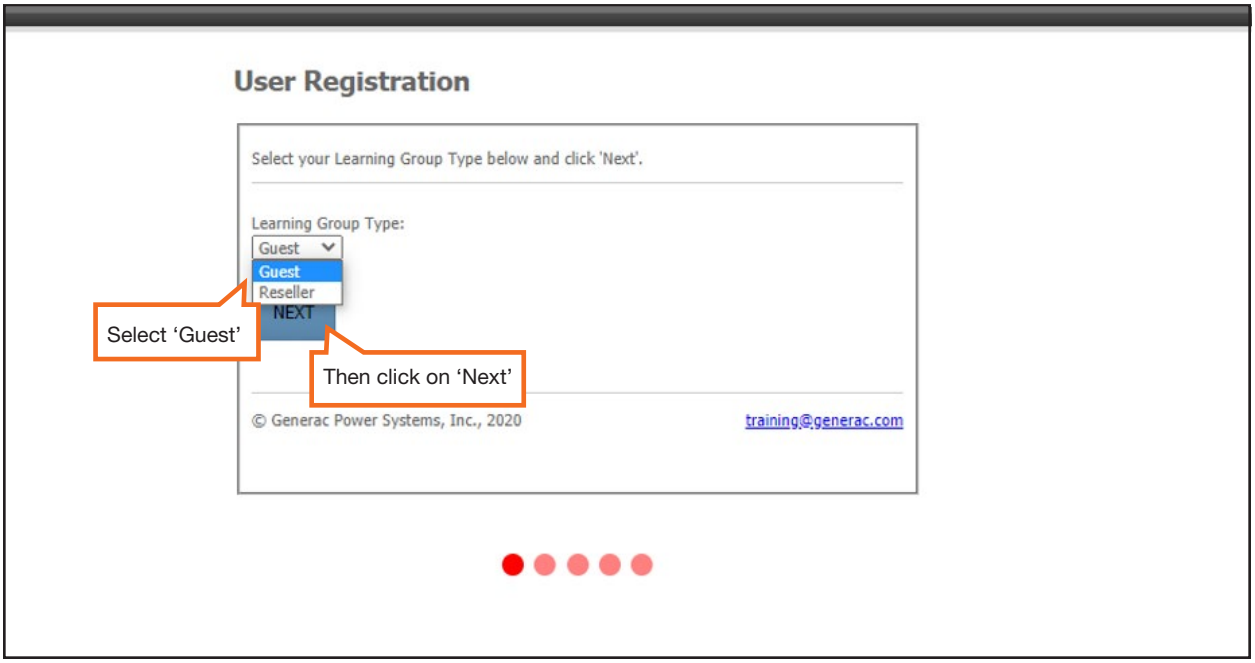
To begin the registration process, open your computer's browser and enter http:// learning.generac.com. This should take you to "The Learning Center" home page. This page is displayed at the top of the next page. From this point you can follow illustrated steps on the following pages.

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 'LOG IN' then the 'register here' link to begin the registration process. If you already have an account, please log in instead of clicking 'register here'.

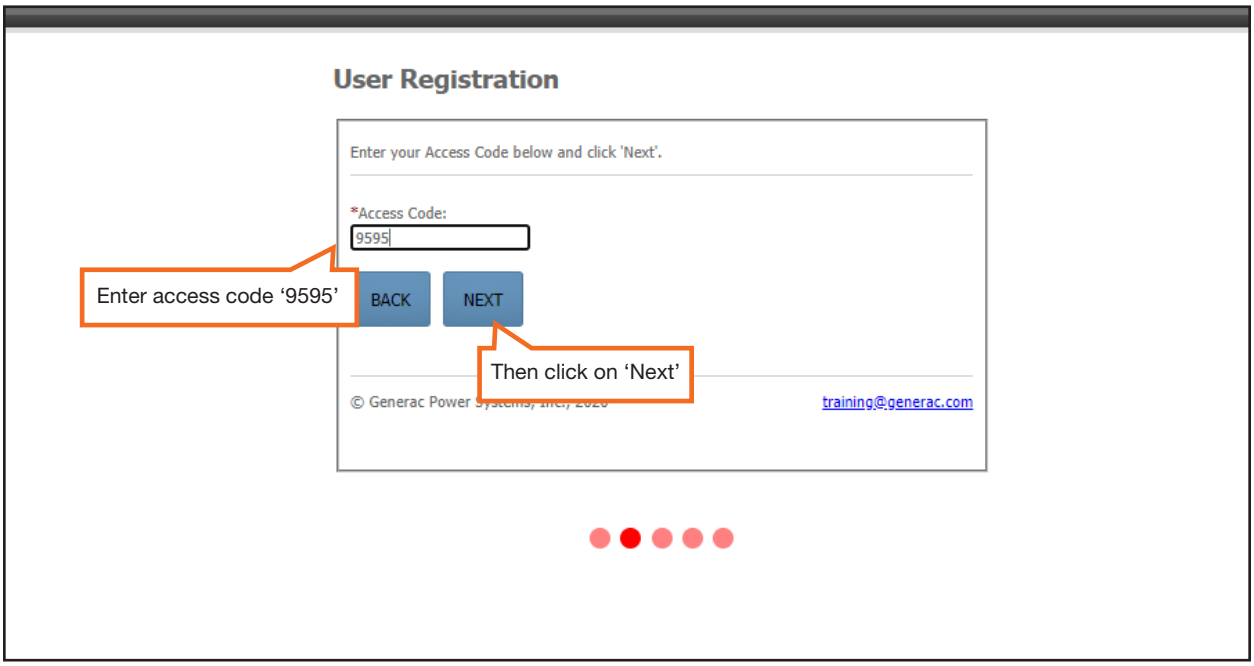


On this screen you will select 'Guest' from the drop down box and click the 'Next' button.

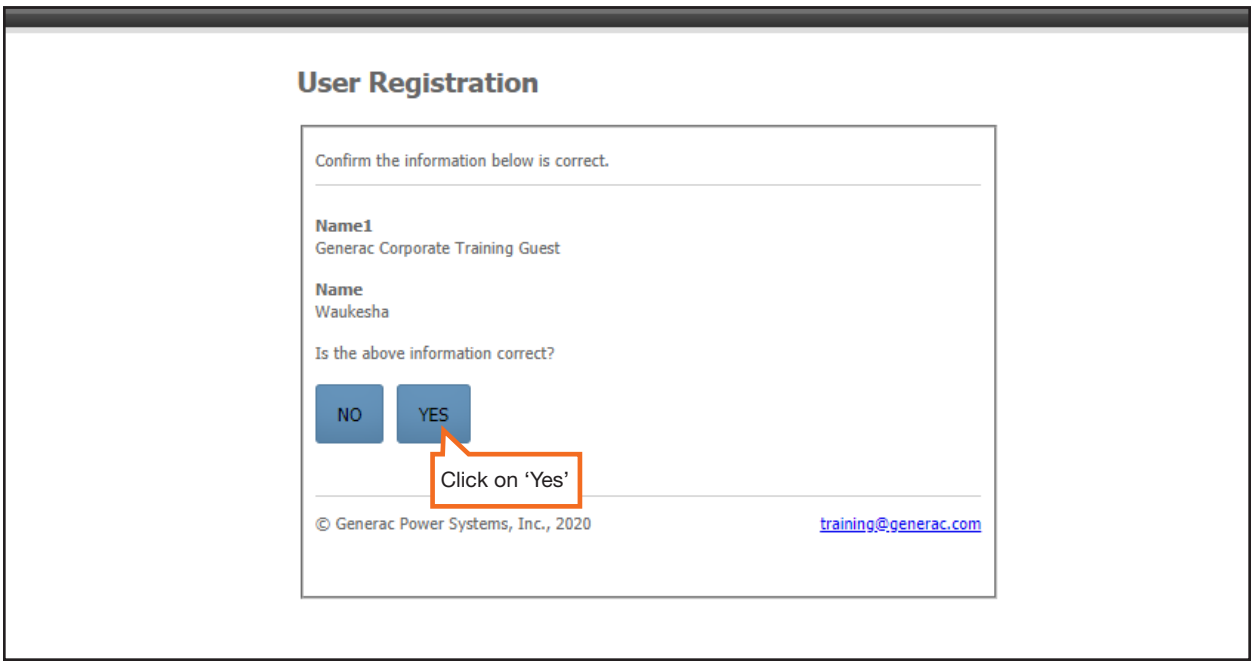


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

In this next screen enter access code ‘9595’ and click the ‘Next’ button. Please keep this code private.

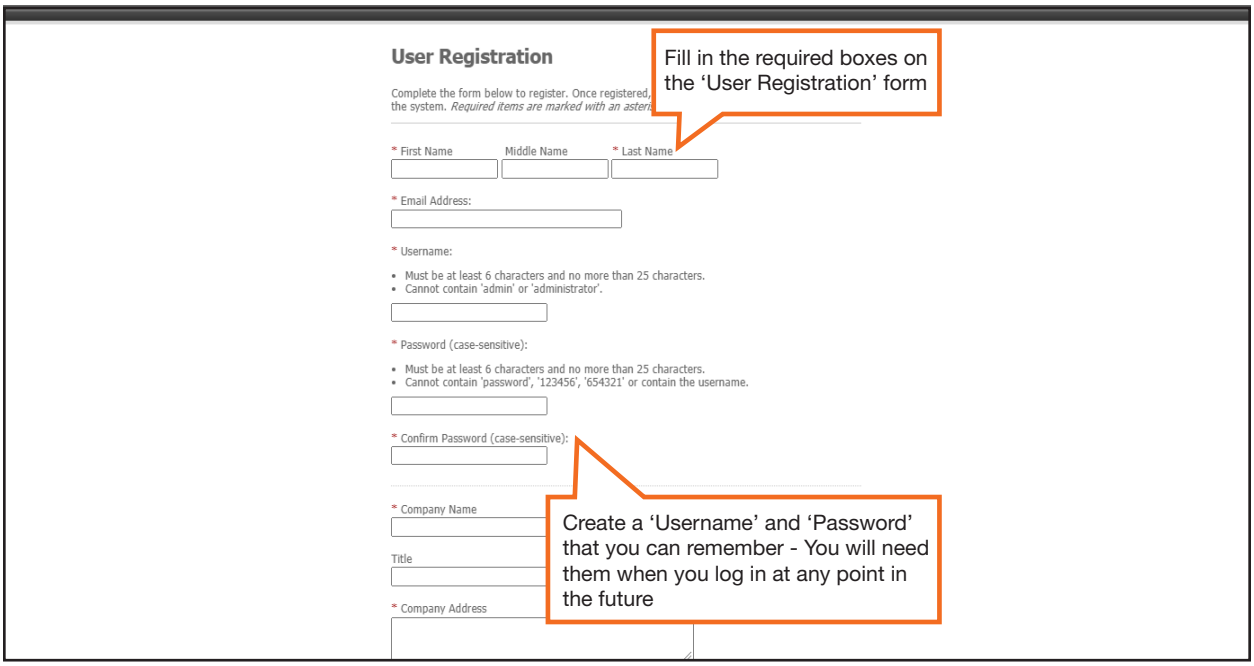


This screen confirms the correct access code entry. Click the ‘Yes’ button to proceed.

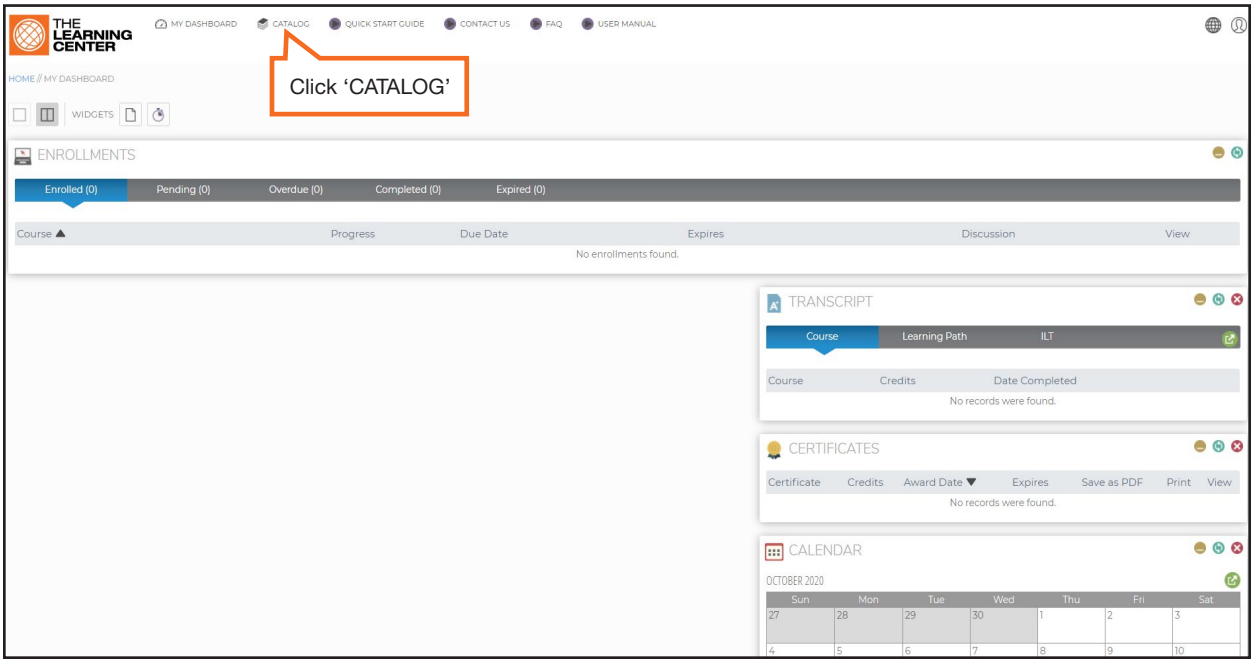


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

The next screen contains the ‘User Registration’ form. Fill in the required boxes and then click the ‘Register’ button.

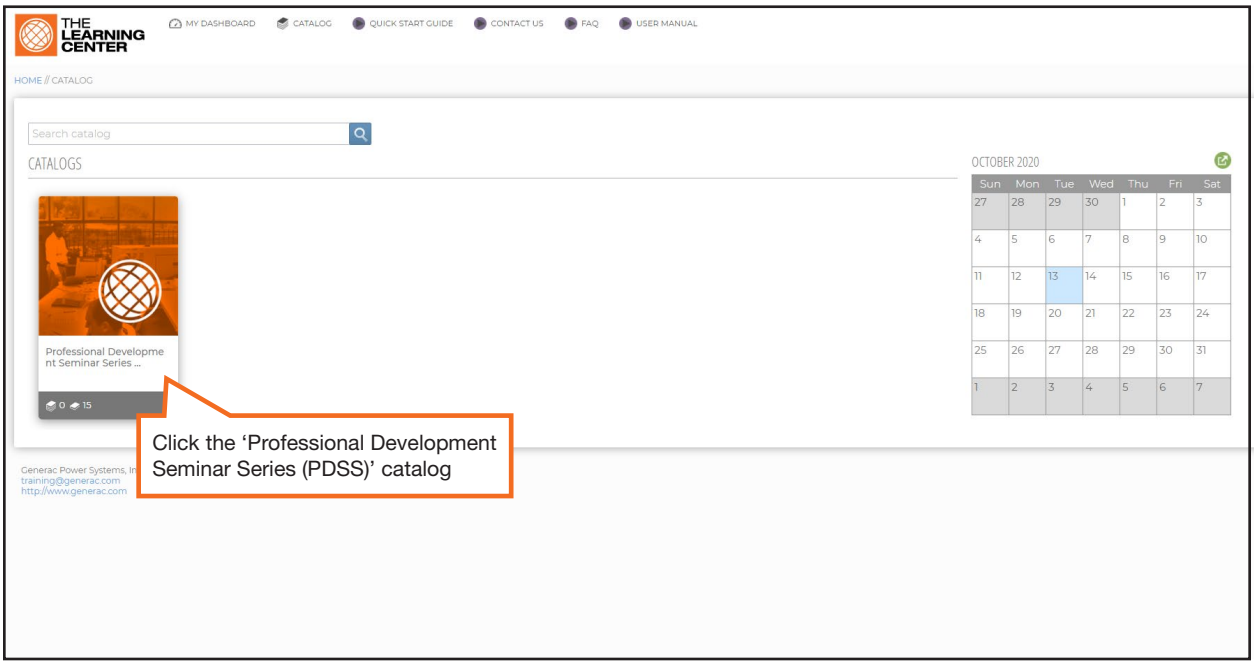


The next screen shows your ‘ENROLLMENTS’. Click the ‘CATALOG’ button to proceed.

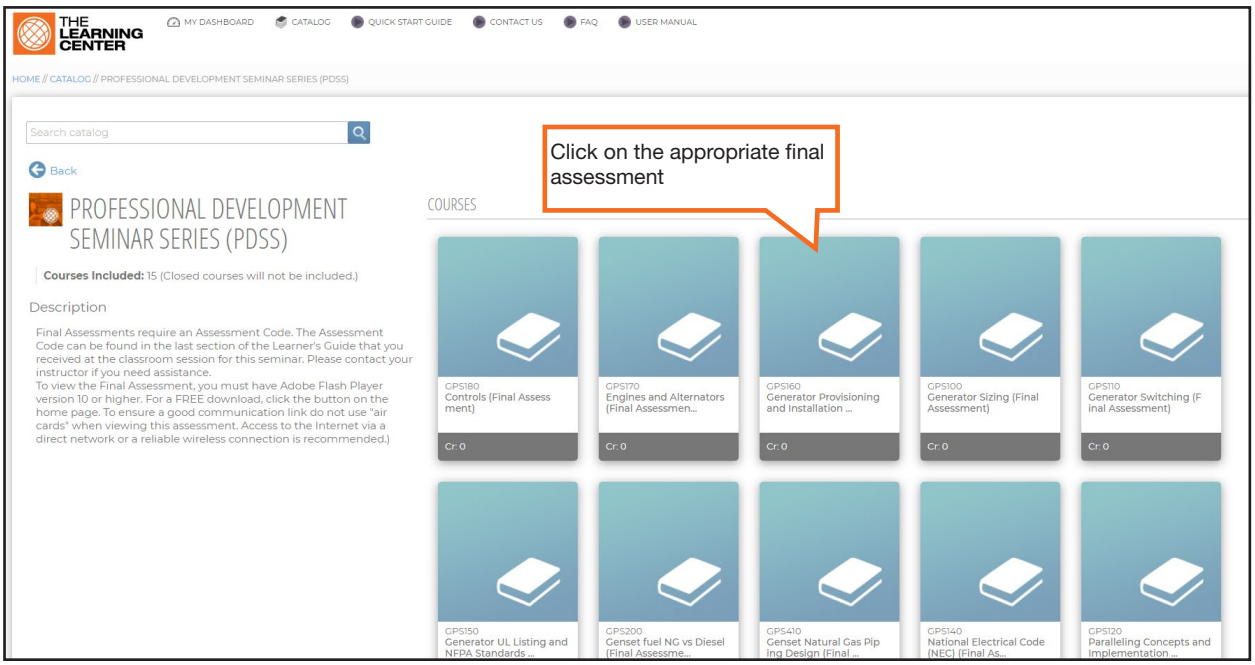


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

The next screen displays ‘CATALOGS’. Click on the ‘Professional Development Seminar Series’ catalog.

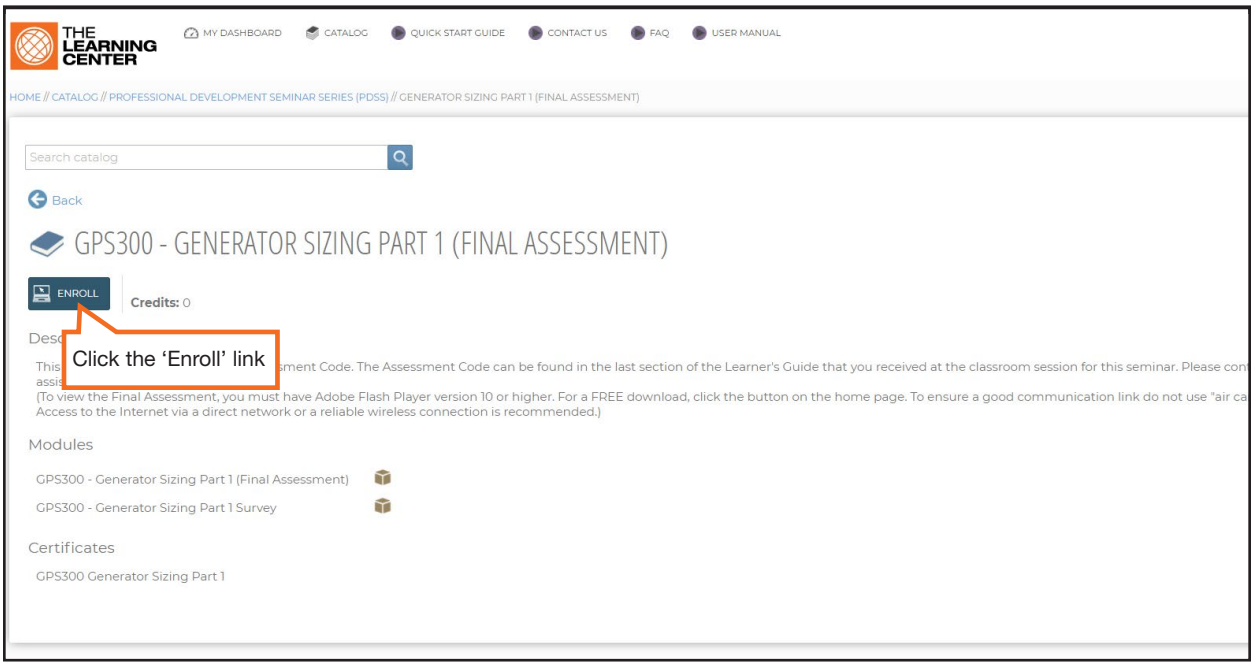


This next screen lists all currently available final assessments. Click on the final assessment that is tied to the course name and number you completed.

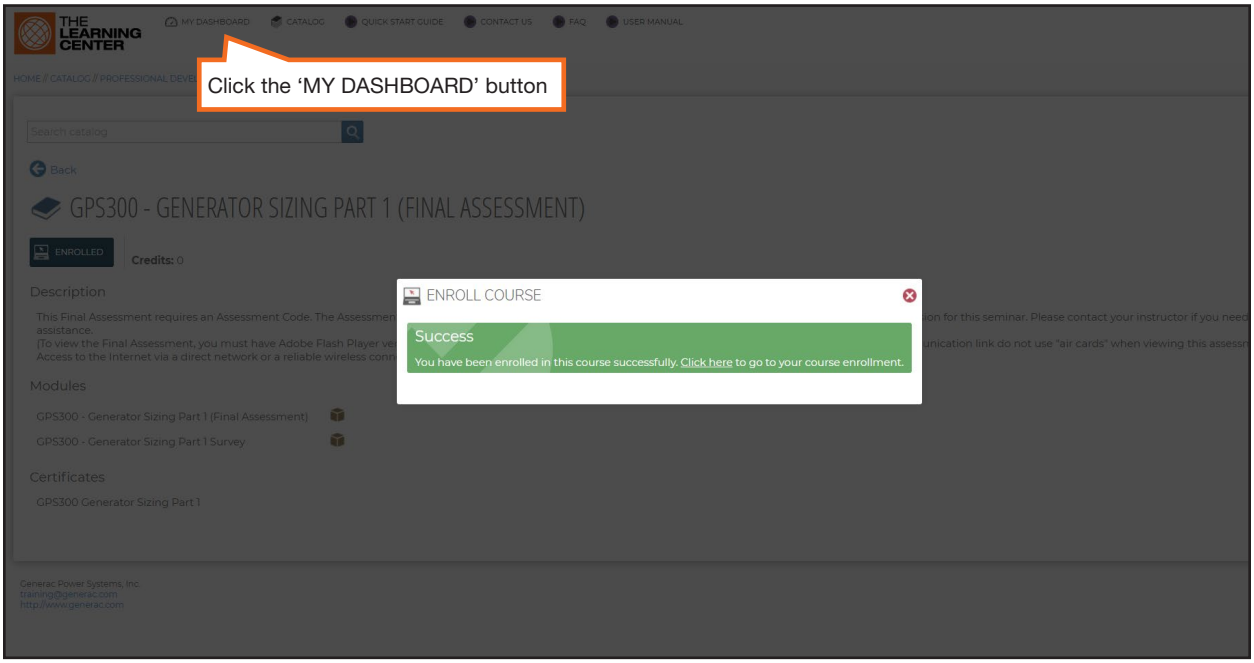


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

The next screen is the enrollment screen for the final assessment that you selected. Click the ‘Enroll’ link to proceed.

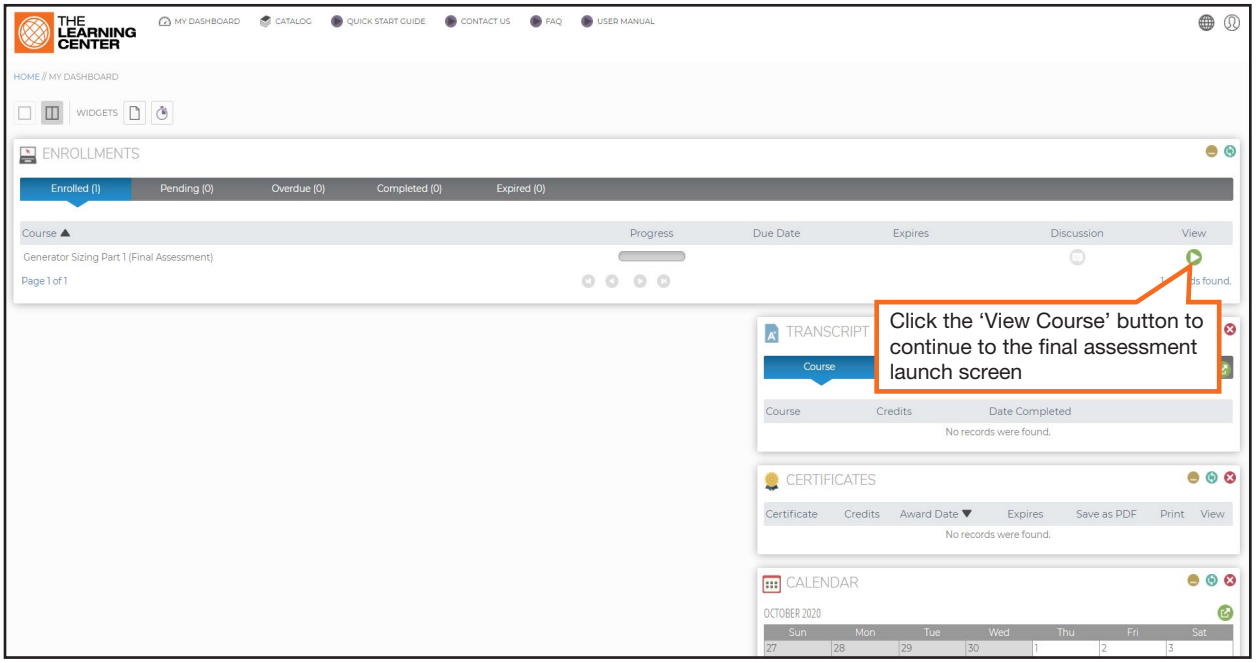


This screen confirms your enrollment. Click the ‘My Account’ button to proceed.

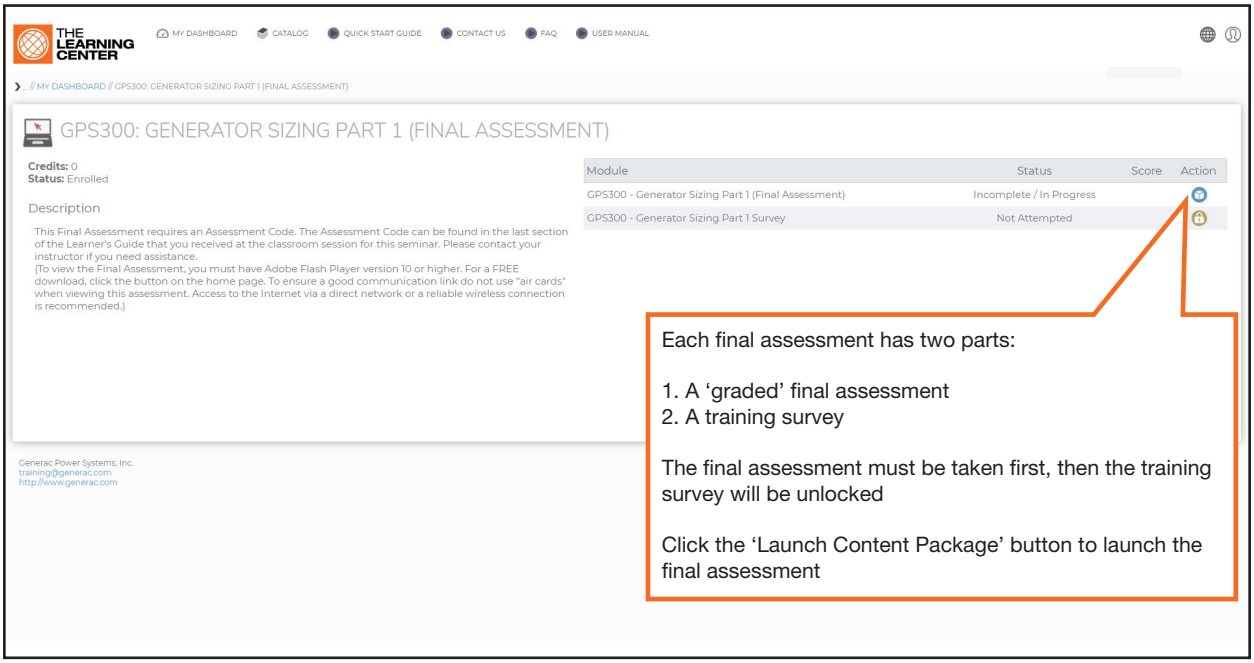


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

This is your ‘MY DASHBOARD’ screen. Note that the final assessment you selected is displayed under ‘Enrolled’ in ‘ENROLLMENTS’. Click the ‘View Course’ button to proceed.

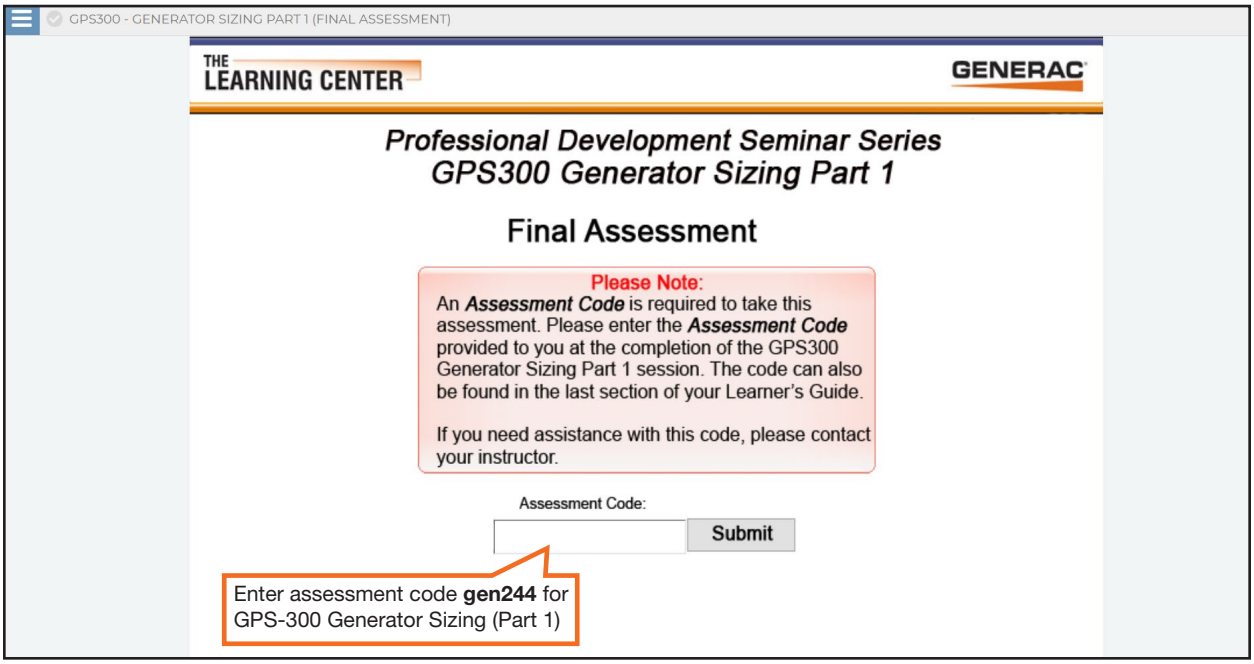


This screen lists the two parts to the final assessment. You must take the ‘graded’ assessment first, then the training survey.

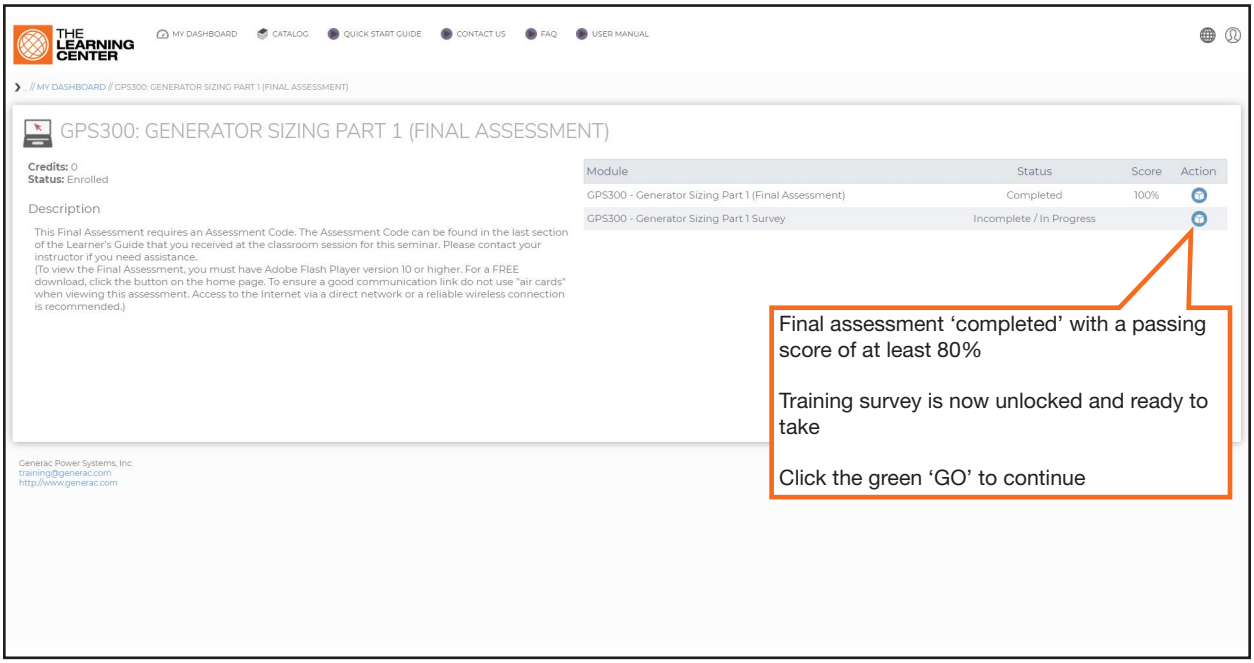


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

In the next screen an assessment code is required before you can continue. The code for GPS-300 Generator Sizing (Part 1) is **gen244**. Enter the code in the box and click the 'Submit' button to continue. From there follow the prompts to complete the 10 question assessment.

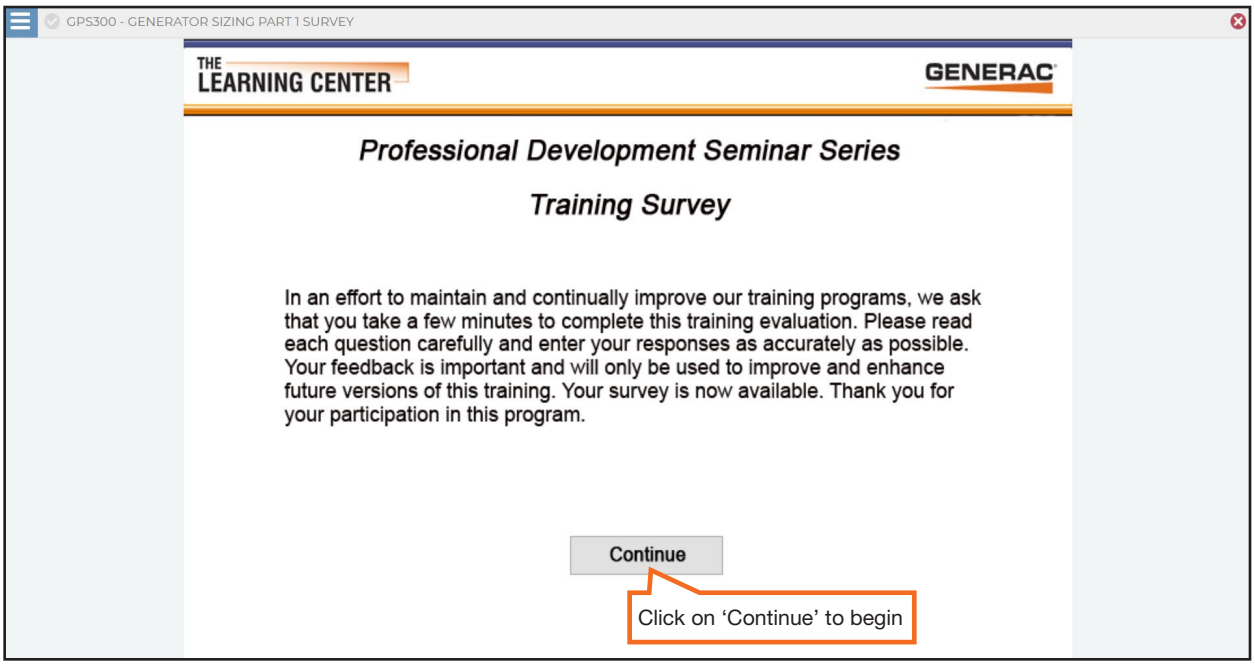


This screen will be displayed after your assessment data is saved. Note that in this example the assessment was passed with a score of 100% and the survey is unlocked and ready to launch.

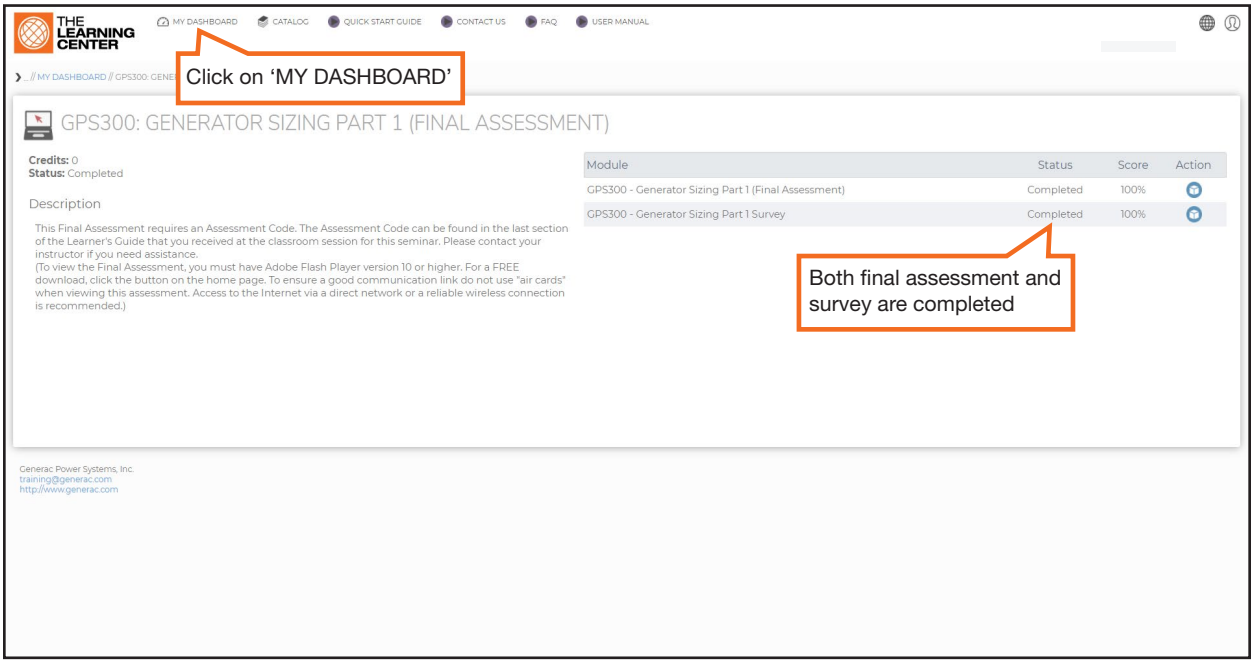


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

Upon launching the survey, this screen will be displayed. Follow the on screen prompts in order to complete.

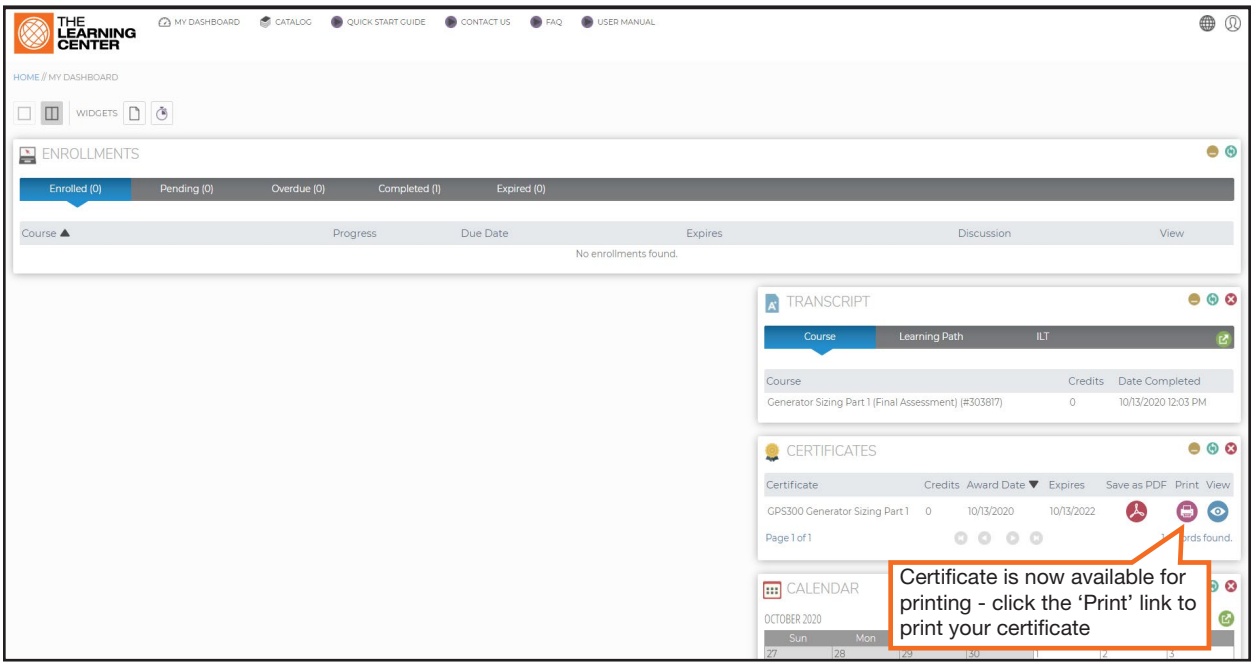


After completing the survey you will be prompted to return to the assessment menu. Your response data will be saved as before, and you will see the screen below. Click the 'MY DASHBOARD' to continue.



ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

Your ‘MY DASHBOARD’ screen will look similar to the one shown here. Click the ‘Print’ link to print your certificate.



NOTES

Part No. GPS300-LEARNER
Rev. 10/2020

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