PROFESSIONAL DEVELOPMENT SEMINAR SERIES

GPS-305
Generator Sizing (Part 2)

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 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 focuses on isolating loads onto a generator where the uniqe characteristics of the load become very important. Loads of particular interest are non-linear harmonic producing loads, uninterruptable power supplies (UPS), variable frequency drive (VFD), soft starters, and older technology electromechanical starters (wye/delta). For each of these loads the resulting load transient and harmonic issues will be explored relative to their impack on generator sizing.

TIME:

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

LEARNING OBJECTIVES:

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

- Analyze different harmonic load characteristics relative to generator impact
- Utilize Generac's Power Design Pro™ sizing software
- Understand the impact of voltage ramping versus stepping when applying soft starters
- Explain the impacts of regenerative power in cable elevator applications
- Identify different UPS technologies and their impact on generator sizing criteria
- Anticipate the impact of early voltage transition when using wye/delta fire pump starters

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:

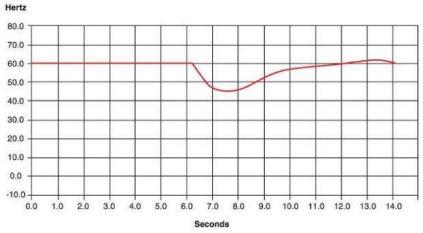
- Attended the complete seminar
- A minimum score of 80% on the final assessment



Matching Load Characteristics to the Generators

- **Sizing Larger Applications**
  (Focus of Generator Sizing (Part 1))
  - No single load is all that important (many mixed load types)
    - Add up total kW
    - Identify the largest transient load (typically an across the line starting motor)

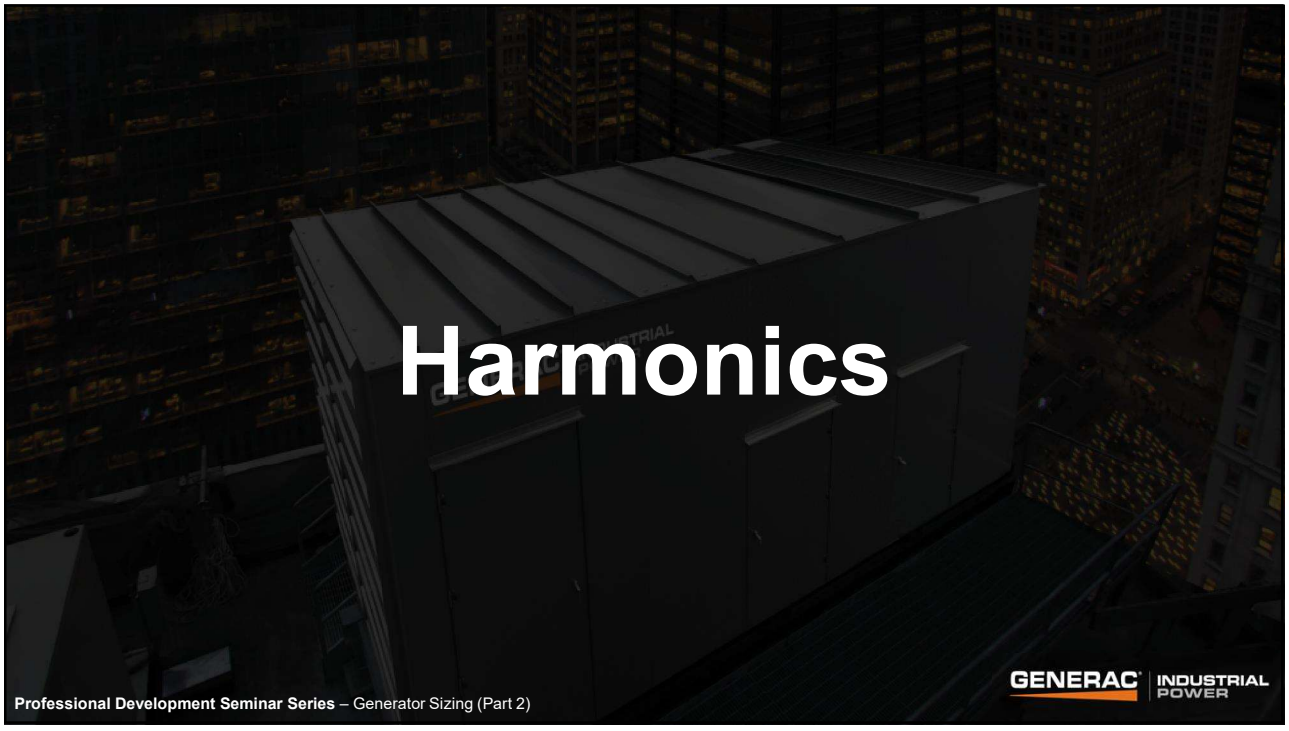
- **Isolating Loads & Smaller Applications**
  (Focus of this session Generator Sizing (Part 2))
  - Characteristics of the load is important
    - Accurate modeling of the load characteristics is important
    - Transients (starting kVA& starting kW)
    - Harmonics
  - Characteristics of the Genset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



Agenda

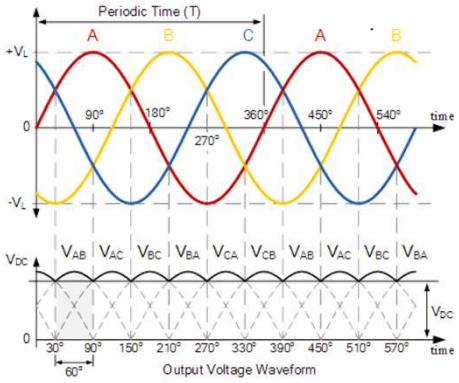
- **Agenda**
  - Planning and sizing for harmonics (filtering and alternator upsizing)
  - Some harmonic issues can't be anticipated (ex. IGBT early implementations)
  - Soft starters (setup impacts generator sizing)
  - VFDs and regeneration (elevators & cranes)
  - UPS sizing (technology type matters)
  - Fire pumps (normal and mechanical over-ride starting)
  - Wye/delta starters (planning for early transitions)

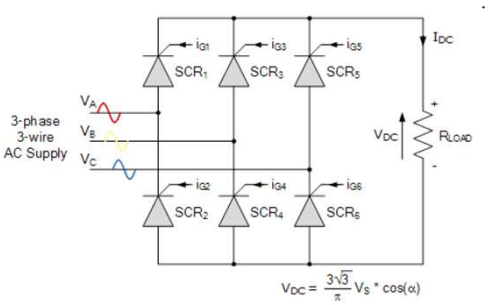
POWER DESIGN PRO™



Harmonic Analysis

- **A non-linear load is often one of the following:**
  - Computers, UPS, VFD, battery chargers
  - AC converting to DC



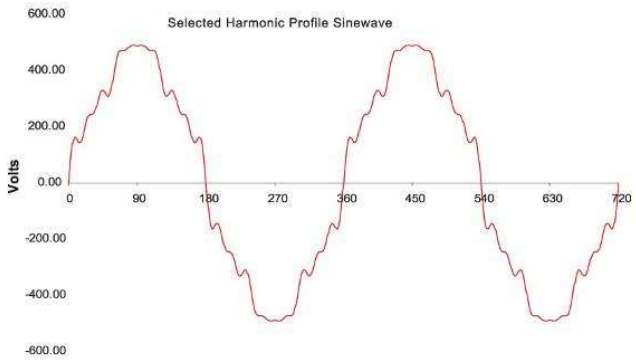


*Source: electronics-tutorials.ws

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Harmonic Analysis

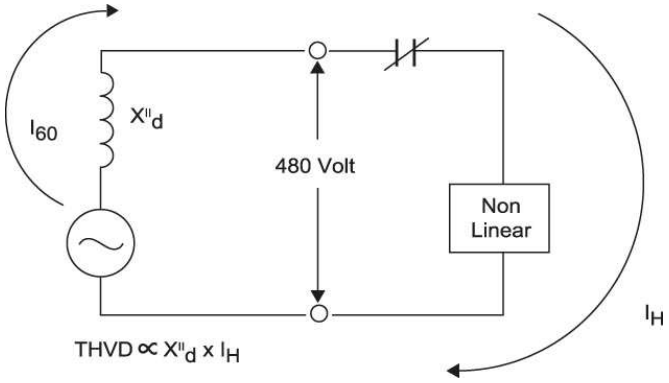
- **How Does A Non-linear Load Affect A Generator?**
  - It causes harmonic voltage distortion (THVD)
  - This is 10% voltage distortion – maximum limit of IEEE 519 – 1992
    - IEEE 519 – 2014 focused on utility perspective requiring 8% at point of common coupling



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Harmonic Analysis

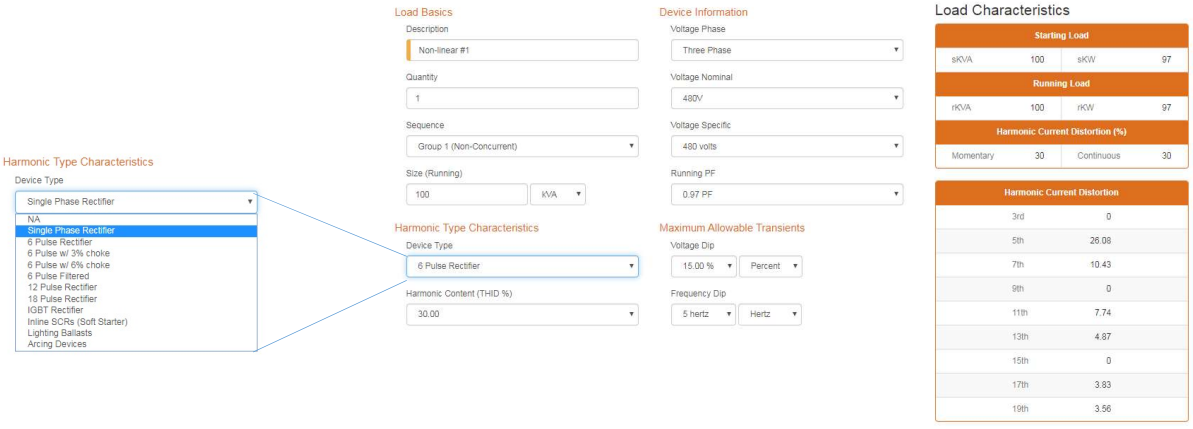
- **Why Are Generators Affected?**
  - Load generates harmonic currents
    - Harmonic currents flow through the alternator's source impedance
    - Ohm's Law: $V = I \times R$ or $THVD \propto X''_d \times I_H$



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Harmonic Analysis

- **Power Design Pro**
  - Device type selected assumes THID & harmonic spectrum
  - User over-ride on THID

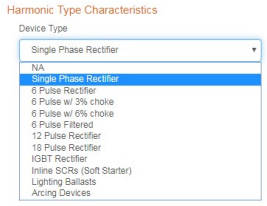


GENERAC INDUSTRIAL POWER

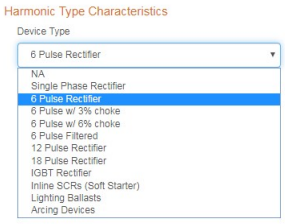
Harmonic Analysis

- **Harmonic Analysis**
  - Select a type of device
  - Tweak the harmonic content %
  - Get a harmonic current spectrum
  - Project the THID against the alternator X"d
  - Get a calculated harmonic voltage spectrum
  - Verify THVD is within acceptable limits
    - Typically limit less than 12%

- **Harmonic Advice**
  - Upsized alternators
  - Better devices
  - Filter the worst offender
  - Use active harmonic filters



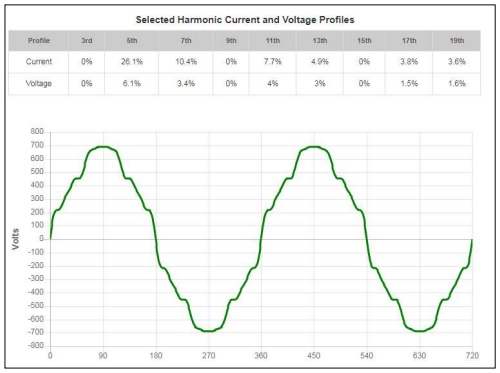
Harmonic Current Distortion	
3rd	38.41
5th	10.52
7th	9.6
9th	2.74
11th	9.15
13th	11.89
15th	0
17th	7.77
19th	7.32

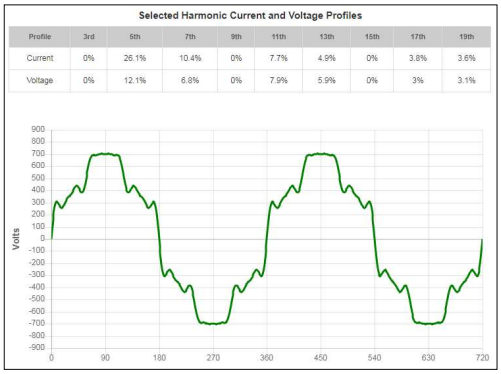


Harmonic Current Distortion	
3rd	0
5th	26.08
7th	10.43
9th	0
11th	7.74
13th	4.87
15th	0
17th	3.83
19th	3.56

Harmonic Analysis

- **Don't Rely Heavily On "Rules Of Thumb" For Harmonic Loads**
  - Rely on harmonic analysis (Power Design Pro utilizes harmonic analysis)
    - Inputs are harmonic current spectrum and alternator reactance
    - Output is an estimated voltage distortion

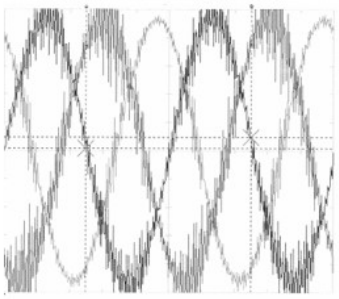




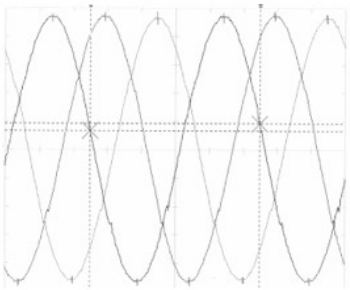
Harmonic Analysis

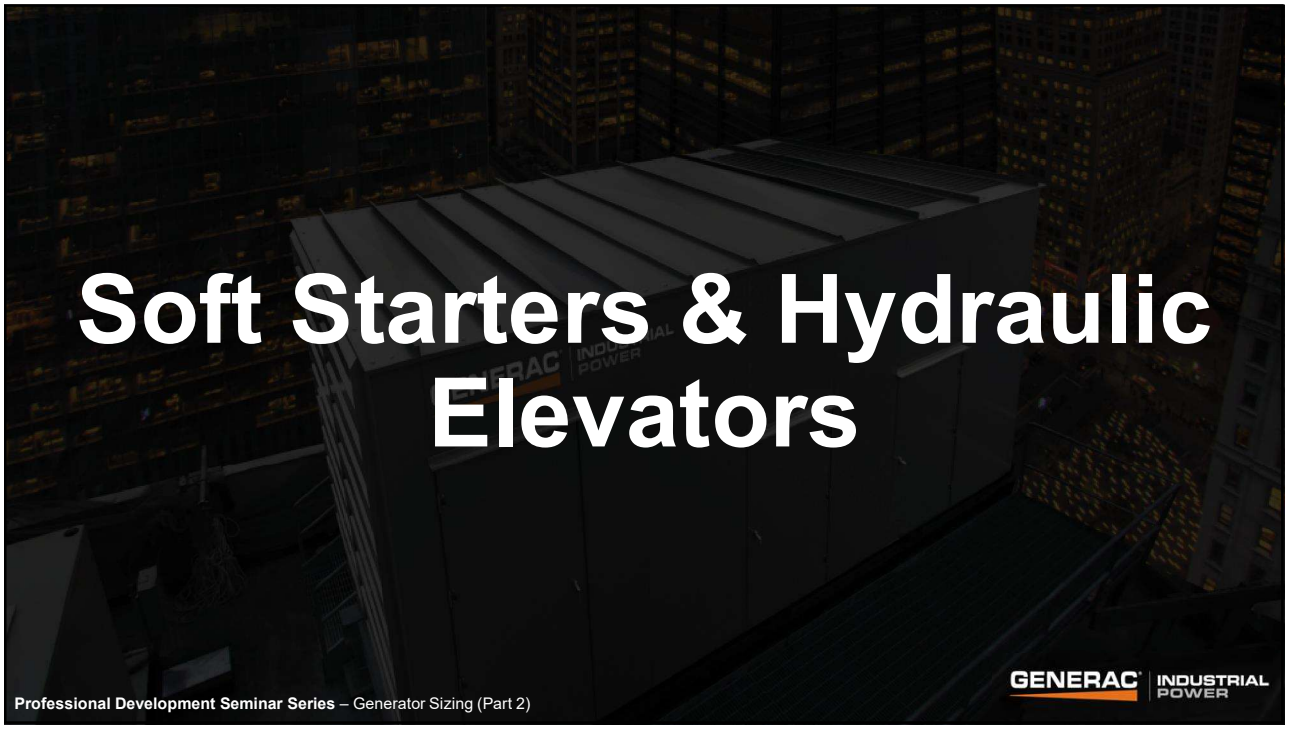
- **Some Problems Can't be Anticipated**
  - When IGBT active PF devices were first applied to UPS's
    - Advertised as low THID, but created significant distortion when isolated on generator
    - OEM's created firmware fixes but older in-field devices can always create surprises

IGBT UPS with
no other load on generator



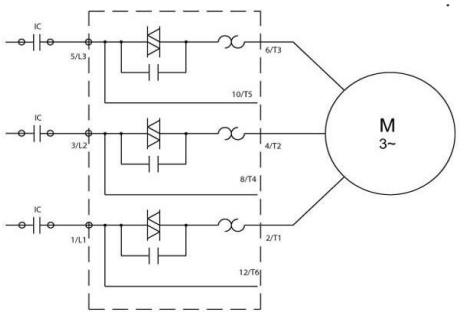
Same UPS with
additional load on generator

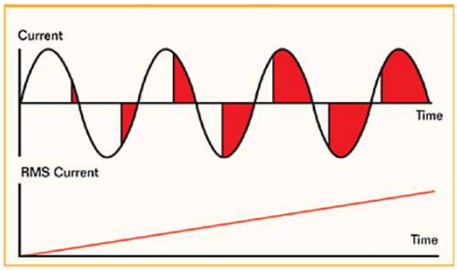




Soft Starters

- **Soft Starters Are An Electronic, Reduced Voltage Motor Starter**
  - Create reduced voltage by only allowing part of the sinewave through to the motor
  - Reduced voltage manages motor's starting torque and acceleration rate
  - Produces harmonics during the starting phase only (bypass functionality)
  - Distortion levels are impacted by current limit setting & system chokes



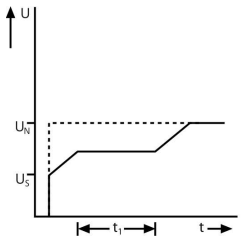


*Source: sprecherschuh.com

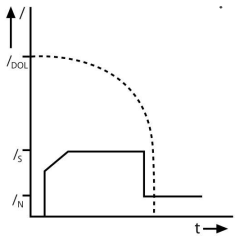
**Source: sites.google.com/site/ucpatnaik/Soft_StartWaveForm.JPG

Soft Starter – Ramping vs Stepping

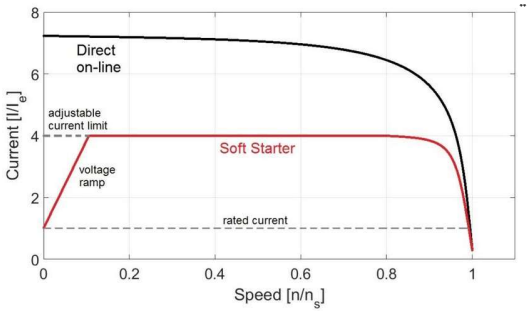
- **Ramping From a Low Level Over a Few Seconds**
  (assumes a low break-away voltage – 20%)
  - No load transient on the generator (smaller generator)
- **Stepping Directly to Current Limit or High Breakaway Voltage**
  - Transient load step on the generator (larger generator to maintain voltage dip)



Softstarter output voltage



Current profile

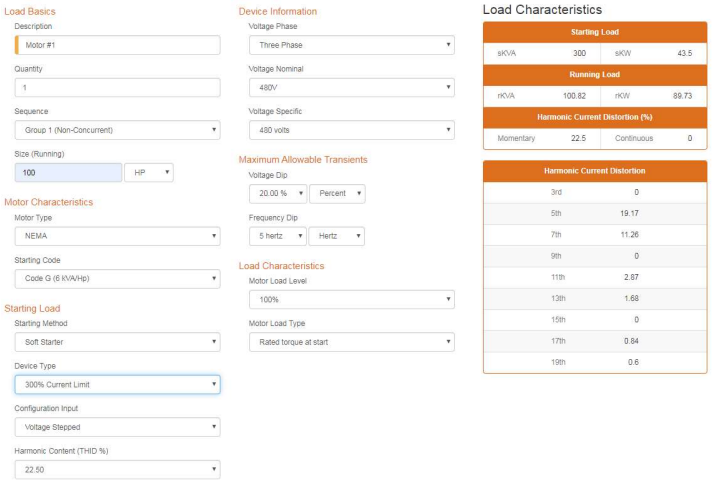


*Source: igelectric.de

**Source: researchgate.net

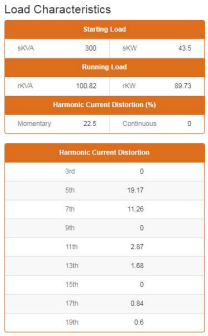
Soft Starter – Power Design Pro

- **Voltage Step**
  - Significant transient
    - SkVA = 300
    - To maintain 20% Vip
    - Alternator = 250kW @ 20 Vdip
- **Voltage Ramp (20% break-away)**
  - Minimum transient
    - SkVA = 120
    - To maintain 20% Vip
    - Alternator = 130kW @ 20 Vdip



Soft Starter – Final Thoughts

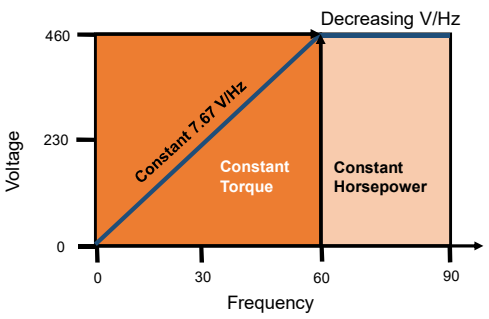
- **Final Thoughts**
  - Allowable voltage dip specifications difficult to find…
    - 20% Voltage dip limit seems workable for general applications
    - Exception is fire pumps, soft-starters, VFDs (15% Voltage dip limit)
  - Utilizing voltage ramping
    - Smaller alternator needed to manage voltage dip
    - Not typically available in hydraulic elevator applications
  - Sequencing (non-current starting)
    - Soft starters only produce harmonics while starting
    - Power Design Pro separates momentary and continuous harmonic devices
    - Non-concurrent starting will result in a smaller generator
  - Hydraulic elevators
    - Utilize pump motor with a soft starter
    - Typically has tight 15% voltage dip & only option for voltage stepping



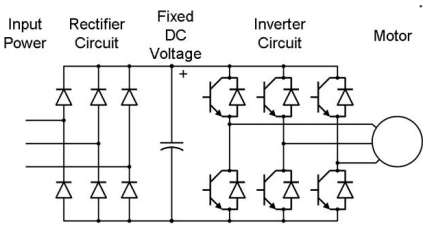


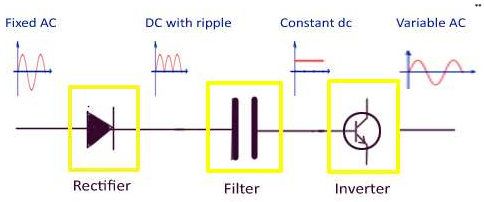
VFD

- **Variable Frequency Drives (VFDs)**
  - Ramp voltage and frequency to the motor
  - Motor has rated torque at all speeds up to 100%
  - VFD is seen as a rectifier by the generator





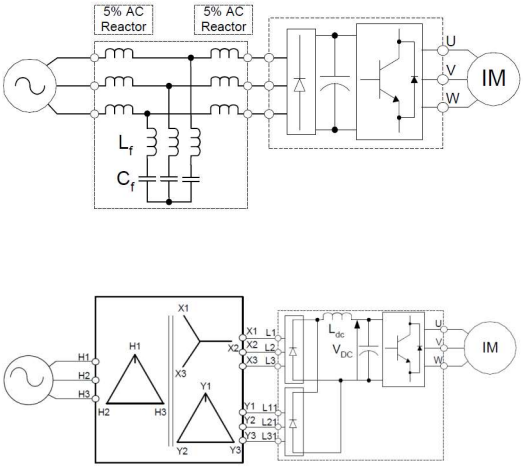




*Source: vfds.org
**Source: sourabhsharmayoutube.com
***Source: abb.com

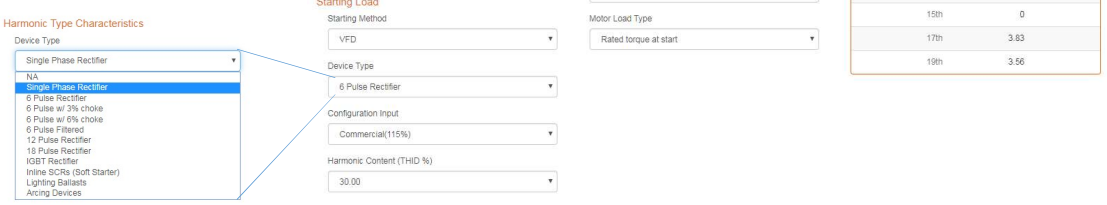
VFD

- **Generator Sizing For VFDs**
  - Voltage & frequency transients are not an issue
    - VFD's tend to walk-in the rectifiers
  - Harmonics are an issue
    - Harmonics are always present
    - Unfiltered 6 pulse fairly common industrial drive
      - Harmonic currents in 30% range
    - Use filtered inputs, higher pulse, or IGBT
      - Harmonic currents in 5-12% range
    - Limit system voltage dips to 15%



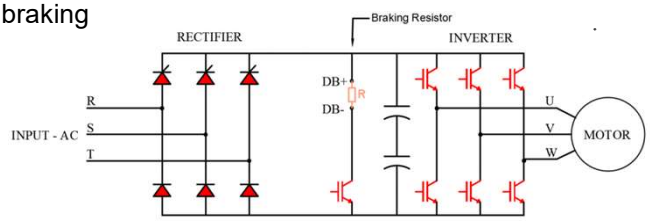
VFD (100 hp) – Power Design Pro

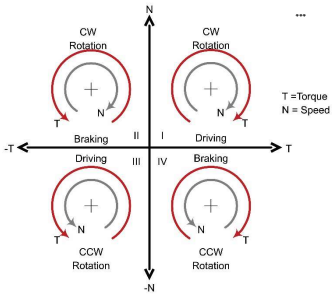
- **Six Pulse Unfiltered**
  - THID = 30%
  - Alternator = 250 kW
  - THVD = 9.5%
- **Six Pulse Filtered**
  - THID = 12.5%
  - Alternator = 100 kW
  - THVD = 10.5%

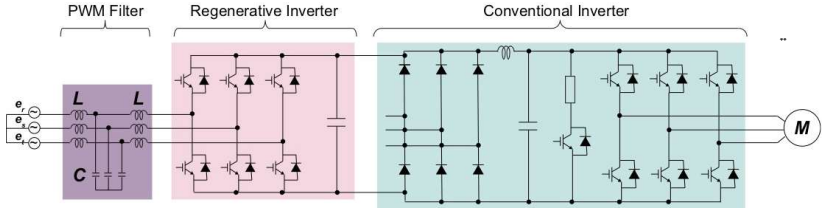


VFD Regeneration – Cable Elevators & Cranes

- **Cable Elevators and Cranes Regenerate**
  - When the load is going down, the drive is a braking
  - Historically breaking resistors
  - Today more regenerative drives







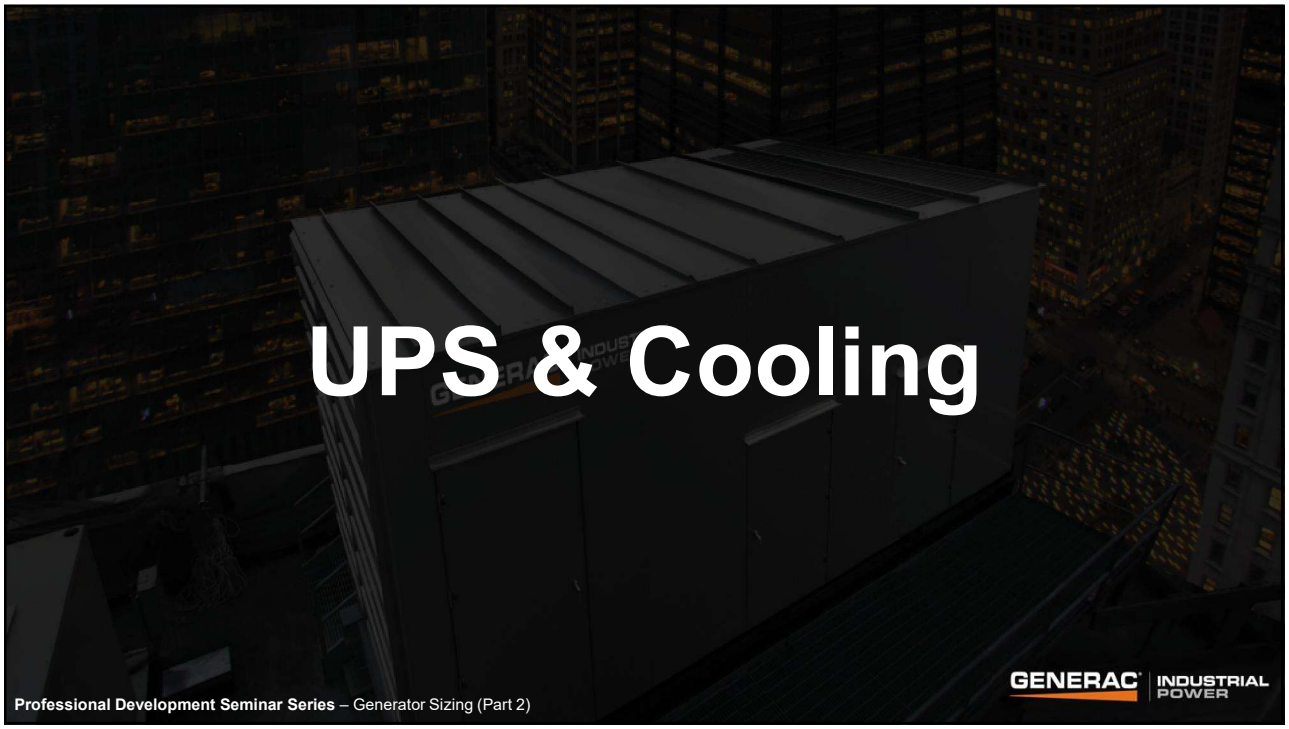
*Source: voltage-disturbance.com
**Source: Yaskawa
***Source: pffc-online.com

VFD Regeneration – Cable Elevators & Cranes

- **Planning for regenerative drives**
  - Regeneration kW = hp x .7
  - How is the power dissipated?
    - Don't rely on the generator as a brake
    - Put other loads on the generator
    - Unit mounted load bank







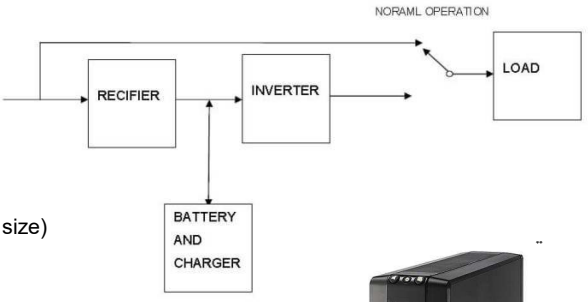
UPS

- **Three Main UPS Classifications**
  - Passive Standby (formerly off-line)
  - Line – Interactive
  - Double Conversion
- **Issues & Sizing Varies By Type**



UPS - Passive

- **Passive UPS**
  - Simple design, low cost and small size
  - Typically single phase, desktop UPS



- **Sizing Concerns**
  - Load is stepped onto generator (not an issue, small size)
  - Harmonics (multiple units, high THID)
    - Size to control voltage distortion
    - Assume high level of current distortion unless specified





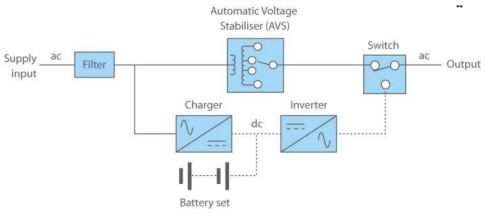
*Source: completepowerelectronics.com
**Source: APC

UPS – Line Interactive

- **Line-Interactive**
  - Provides some output voltage regulation & no frequency regulation
  - Small power applications not utilizing a generator



- **Sizing Concerns**
  - UPS sensitive to frequency variations (.5 Hz factory default)
  - Load steps from UPS itself are often the main issue
  - Open UPS frequency window to allowable limits (2 Hz plus)
  - Size based on frequency transient
  - Harmonics may also be extensive (if not filtered)



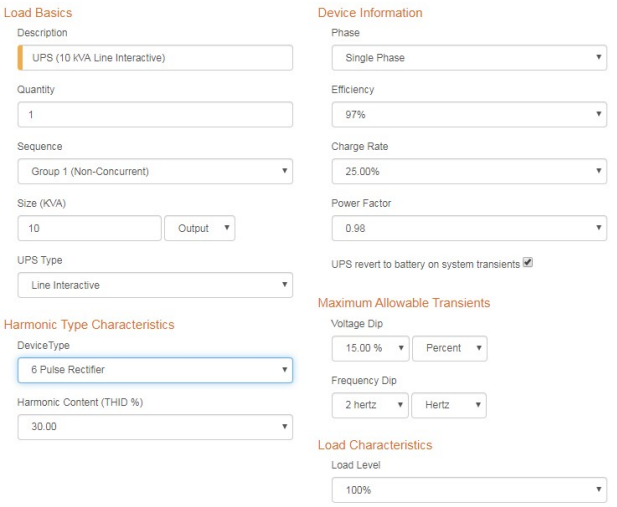
*Source: EATON
**Source: constantpowerservices.com

UPS – Line Interactive

- **UPS Sizing**
  - Tight frequency limit (2 hz default)
  - UPS creates a load step (skW)
  - Option to allow UPS to revert to battery
    - HVAC will need large window of operation

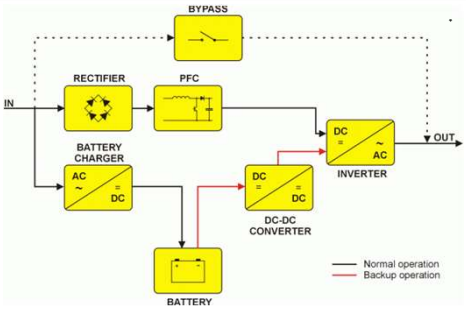
Load Characteristics

Starting Load			
sKVA	12.81	sKW	12.55
Running Load			
rKVA	12.81	rKW	12.55
Harmonic Current Distortion (%)			
Momentary	30	Continuous	30



UPS – Double Conversion

- **Double Conversion**
  - Output voltage & frequency regulation
  - Market norm for critical applications & higher power ratings
  - No UPS load step (rectifier ramps load onto generator)
  - Today must use IGBT active input stages (low harmonics)
  - Battery charge rate adjustable (typically 5 – 25%)



- **Sizing Concerns**
  - Retrofit applications confirm UPS harmonic mitigation (size for harmonics)
  - Utilize input “on generator” (avoids UPS going into non generator friendly modes)
  - Consider HVAC requirements
  - Size for kW needs

- **Generator kW Rating Is typically UPS x 2**
  - Assumes room cooling on generator

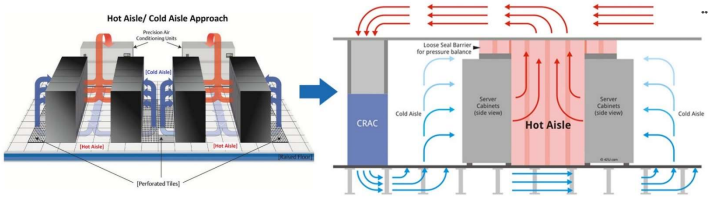
*Source: apecus.com

Cooling

- **Cooling**
  - Compressor rule of thumb (1hp / ton)
    - Ton of cooling = 12,000 BTU, 3412 BTU = 1kWhr,
    - 1kW / Ton = 12 EER (fairly typical)
    - Typically divided into multiple motors (ex 25 ton using 2 x 12.5 Hp)
  - Sequencing
    - Must bleed head pressure prior to restarting (natural sequencing)
    - Can be inter-locked or adjusted for non-current starting



- **Reheat**
  - Added heat for dehumidification
  - Avoids over cooling



*Source: LIEBERT
**Source: cool-shield.com

Cooling

- **Cooling Load Type**
  - Use for initial scope sizing
    - Efficiency
    - Number of compressors
    - Reheat
- **Pull name plate data**
  - Enter as motor loads

Load Characteristics

Starting Load			
sKVA	88.24	sKW	26.47
Running Load			
rKVA	34.41	rKW	30
Harmonic Current Distortion (%)			
Momentary	0	Continuous	0

Load Basics

Description: AC (25 Ton w/ 2 compressor motors)

Quantity: 1

Sequence: Group 1 (Non-Concurrent)

Cooling: 25 Tons

Device Information

Compressors: 2 Compressor Motors

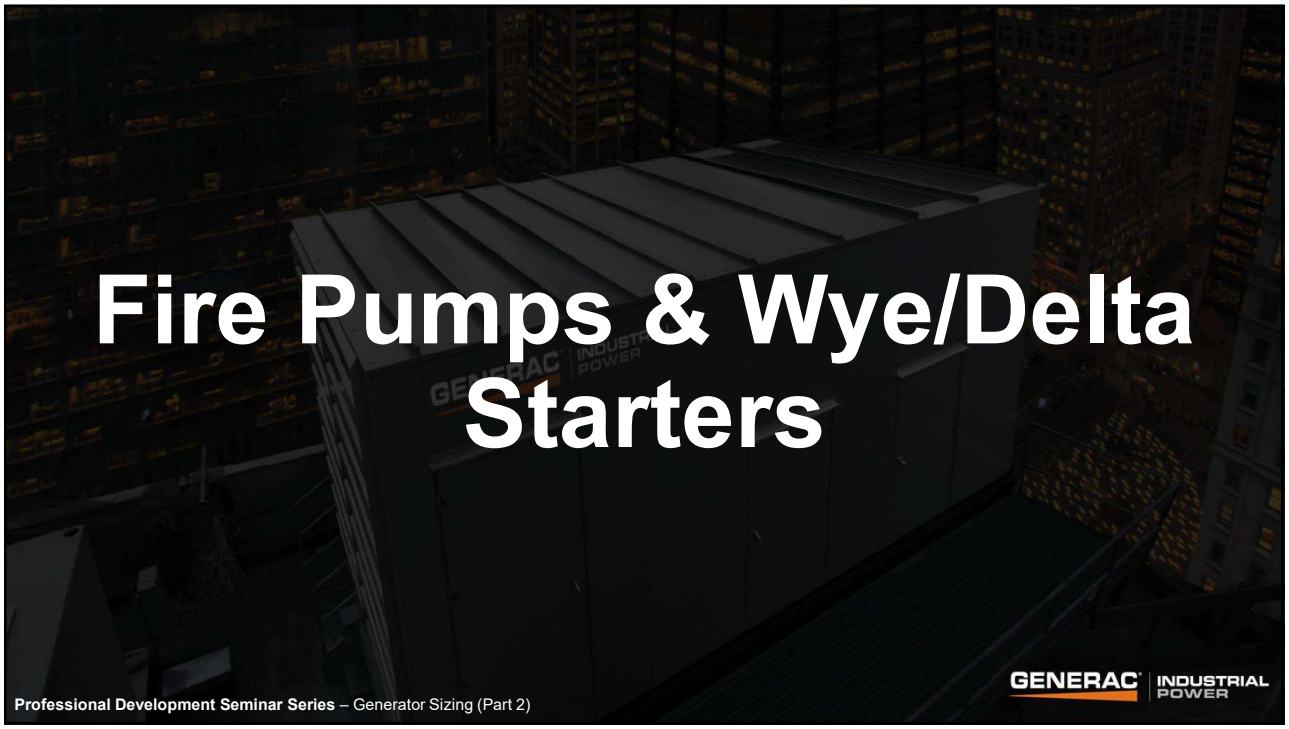
Cooling Load: 1.0 kW/ton

Reheat Load: 0.2 kW/ton

Maximum Allowable Transients

Voltage Dip: 15.00 % Percent

Frequency Dip: 5 hertz Hertz



Fire Pumps

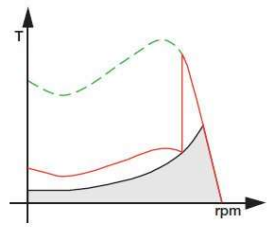
- **Fire Pumps**
  - Normal starting method (15% voltage dip limit)
    - Reduced voltage starting (limits mechanical system stress)
    - Soft-starter (voltage ramp & keep break-away voltage low)
    - Wye-Delta (problem with early transition – torque limit)
    - Reduced voltage equates to reduced motor torque
  - Generator must support mechanical over-ride start
    - Secondary sizing check
    - Across the line start (target 35% voltage dip)

Starting Method	% volts at motor	% skVA	% LR Torque
Full Voltage	100	100	100
Autotrans.			
80% tap	80	64	64
65% tap	65	42	42
50% tap	50	25	25
Star-Delta	57	33	33

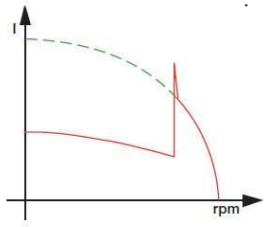
Fire Pump – Wye/Delta Starters

- **What Happens as Speed Increases?**
  - Pump loads up & motor runs out of torque (on reduced voltage)
  - Motor switches to full voltage
    - Motor torque increases
    - System will experience a kVA spike
    - Alternator voltage will dip
    - Most competitive sizing programs do not model this

- **Power Design Pro™**
  - Models early transition
    - Default – low torque at start



Torque/speed curve at Star-Delta start



Current curve at Star-Delta start

*Source: eblogbd.com

GENERAC INDUSTRIAL POWER

Fire Pump – Wye/Delta Starters

- **100 Hp (wye/delta)**
  - "Unloaded at start" assumes motor can reach full speed on reduced voltage
    - Motor would need to have clutch or unloading method
    - What competitive sizing programs utilize
  - "Low torque at start" estimates the early transition skVA spike
    - Matches most real world situations (default setting)
  - "Rated torque at start"
    - Motor transitions at low RPM
    - Like across line start
  - Power Design Pro™
    - Supports all three modes



GENERAC INDUSTRIAL POWER

Sizing Summary

- **Harmonics**
  - Mitigate harmonics at largest loads or upsize alternator
  - Use sizing programs like Power Design Pro that performs full harmonic analysis
- **Soft Starters**
  - Voltage ramping with low break-away voltage (smallest generator)
- **Regenerative VFD's**
  - Plan for connected facility load or load bank on the generator
- **UPS's**
  - Watch frequency window for line interactive technology
  - Confirm harmonics are mitigated or upsize the alternator
  - Use "on-generator" input to the UPS
- **Cooling**
  - Get the nameplate data and enter as motors
- **Fire Pumps**
  - Size for 15% voltage dip and verify capability to do mechanical over-ride start
  - Soft starters with voltage ramp and low break away voltage (preferred)
  - Wye/delta starters transition early (use programs like Power Design Pro that model this)

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":

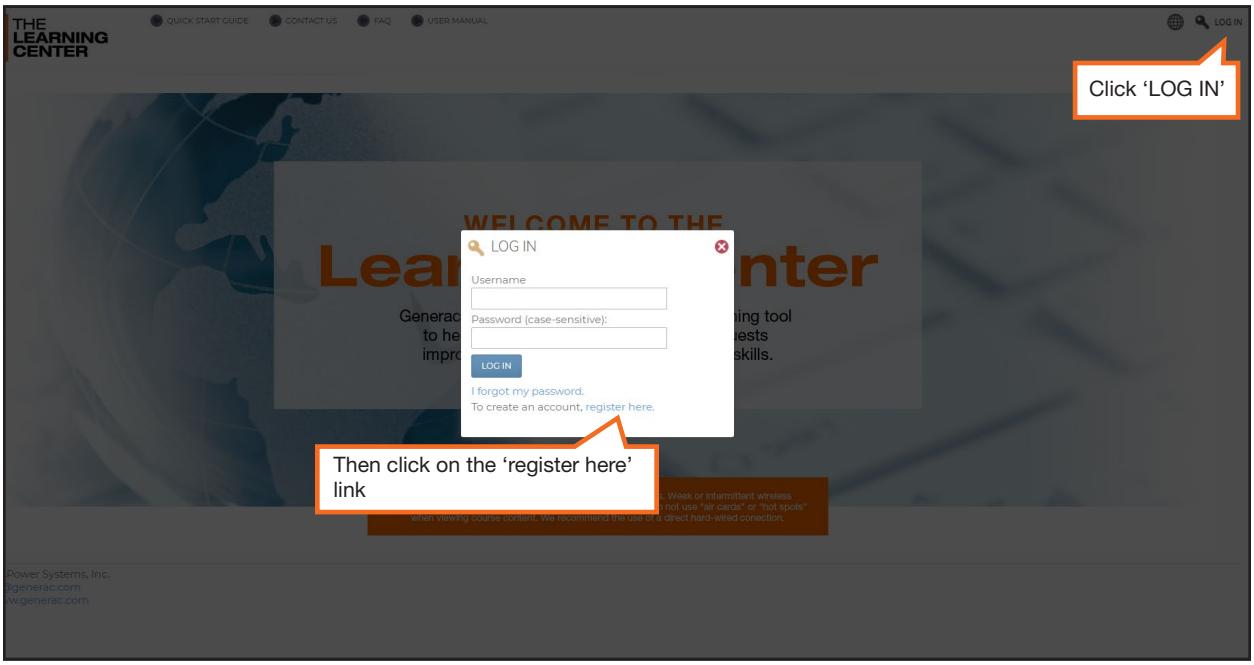
To gain access to "The Learning Center", you are required to register and set up a user account. During your account setup you will create a username and password. Your username and password can then be used to log in on subsequent visits.

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

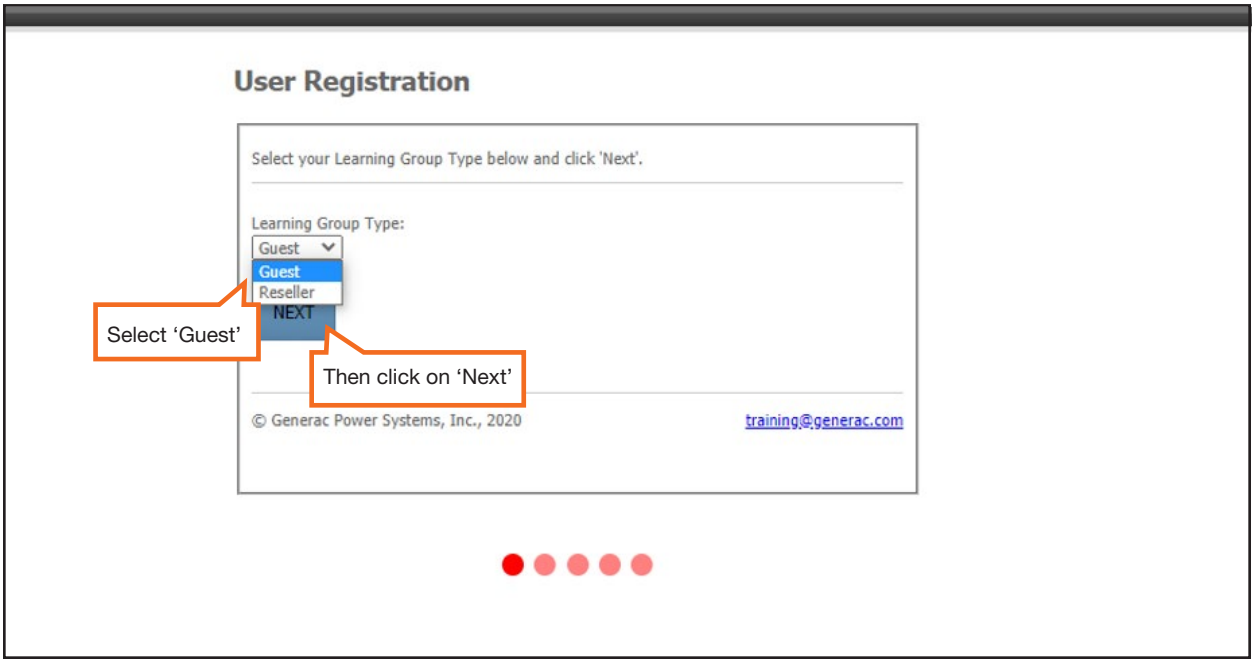
To begin the registration process, open your computer's browser and enter http:// learning.generac.com. This should take you to "The Learning Center" home page. This page is displayed at the top of the next page. From this point you can follow illustrated steps on the following pages.

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'.

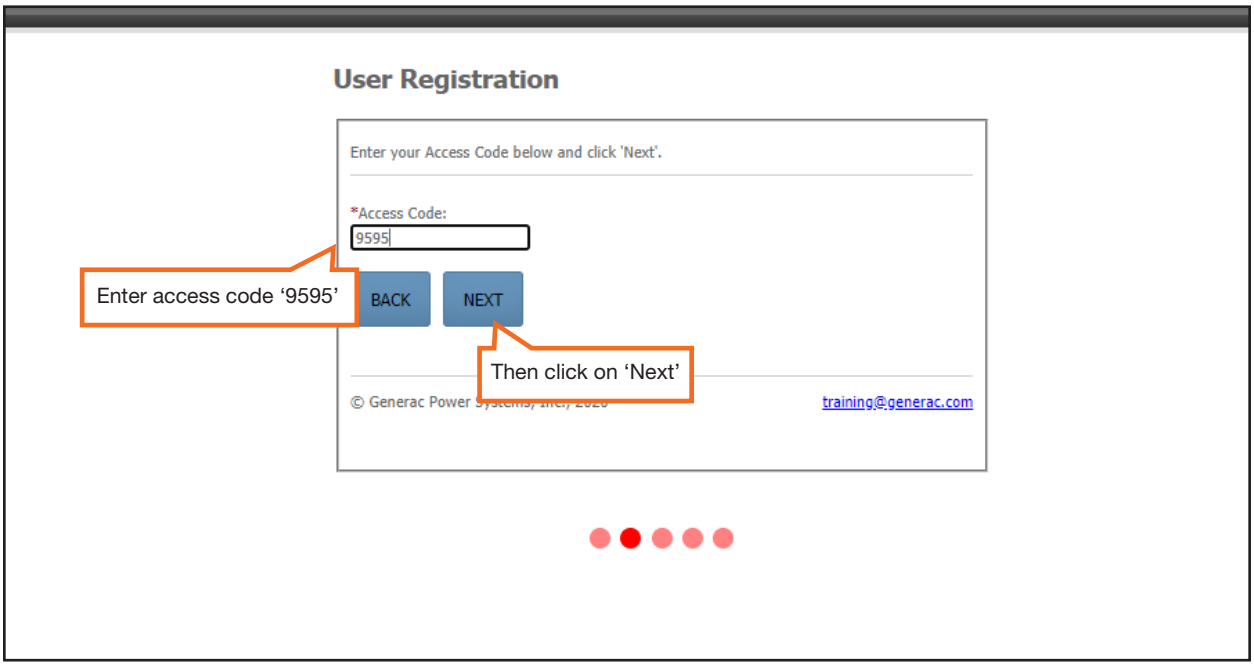


On this screen you will select 'Guest' from the drop down box and click the 'Next' button.

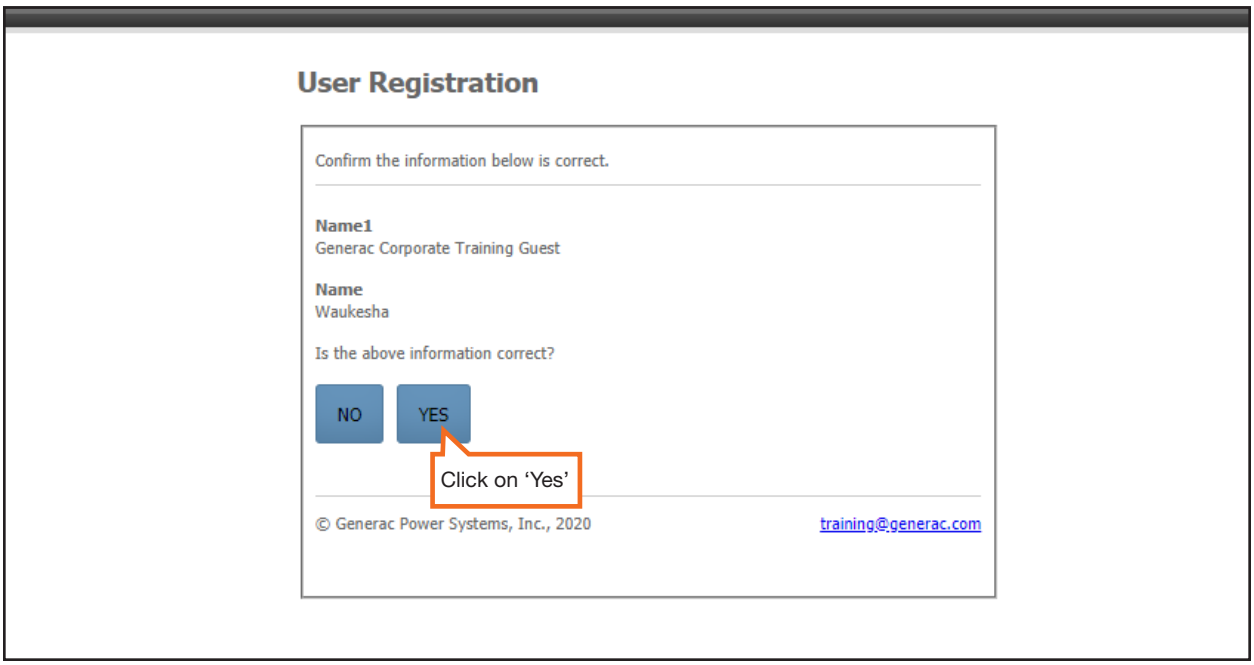


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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

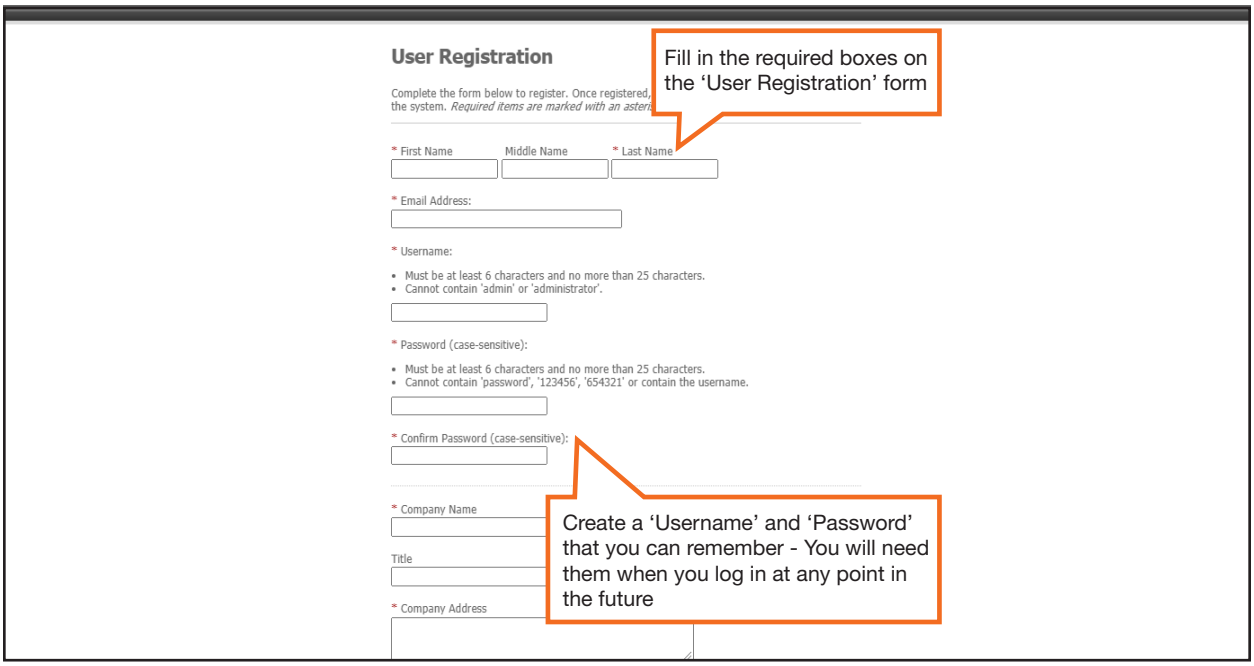


This screen confirms the correct access code entry. Click the ‘Yes’ button to proceed.

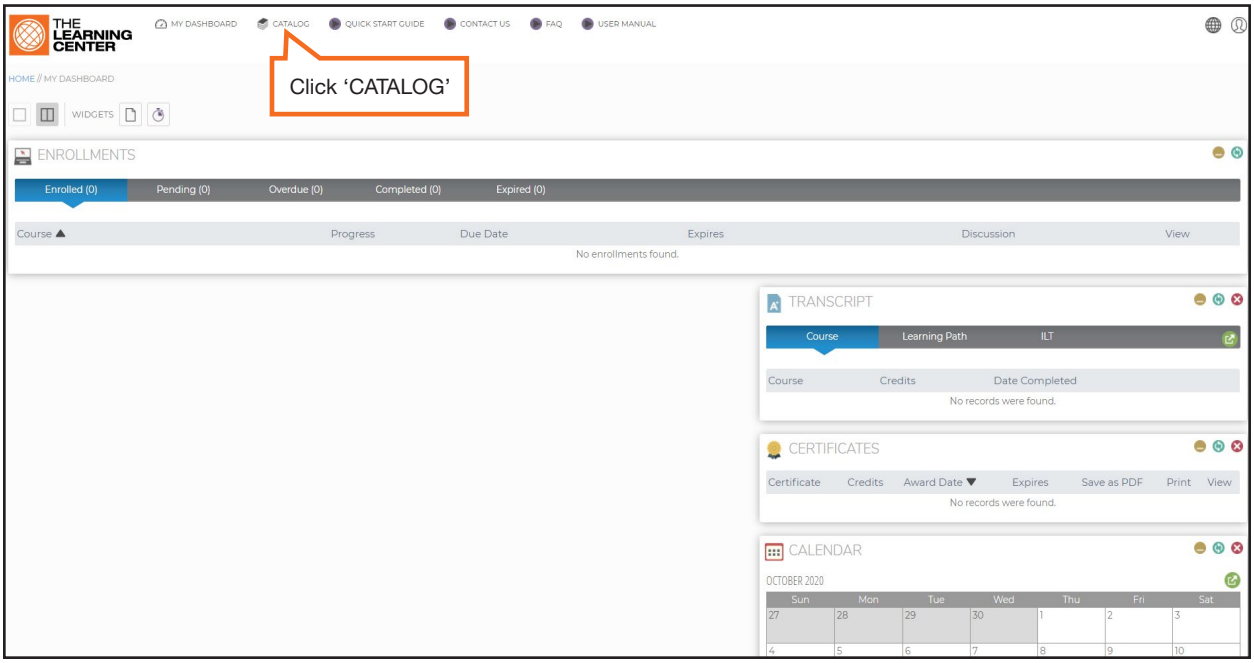


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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

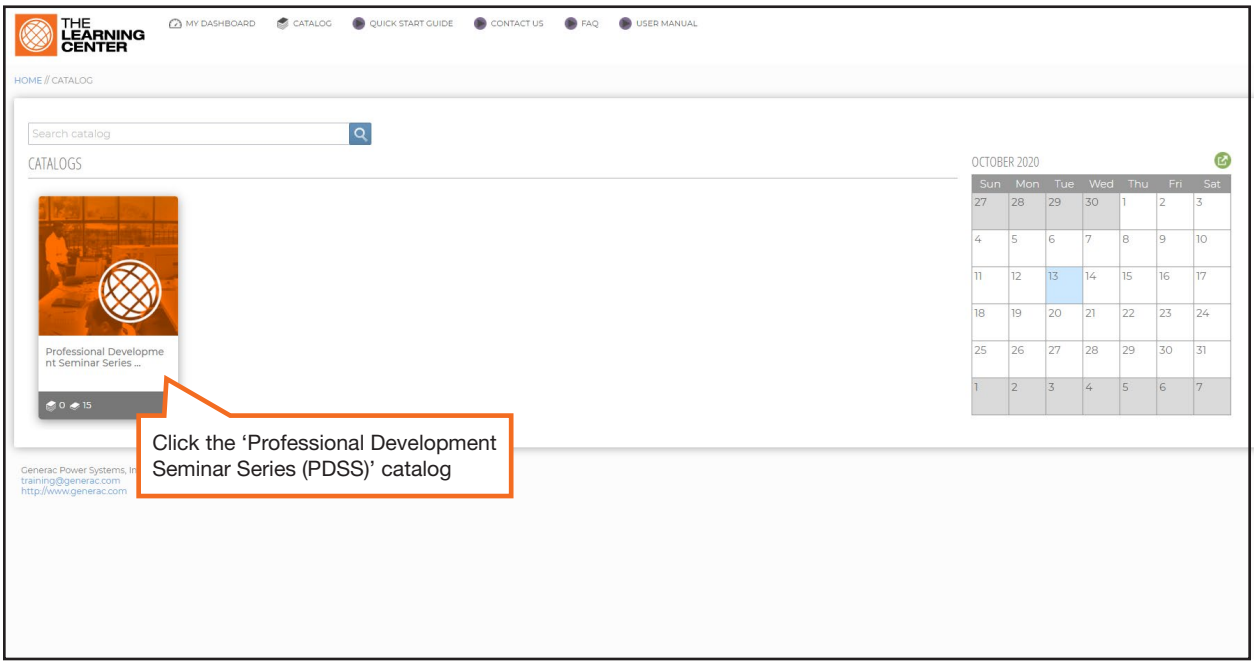


The next screen shows your ‘ENROLLMENTS’. Click the ‘CATALOG’ button to proceed.

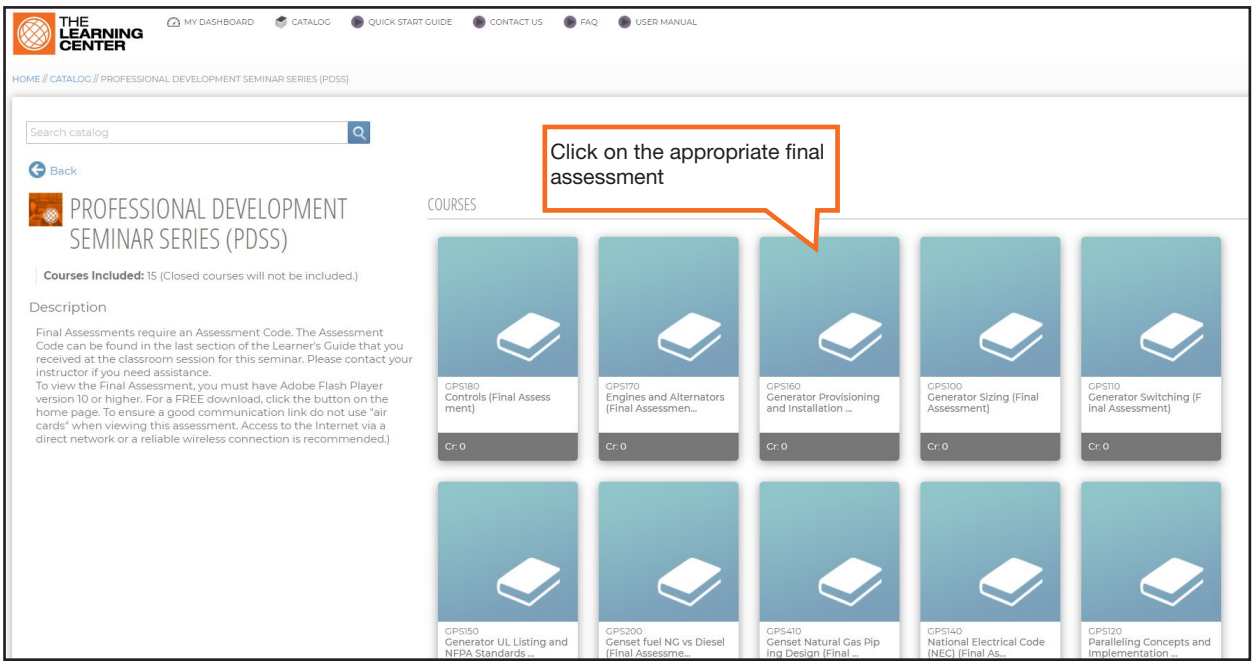


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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

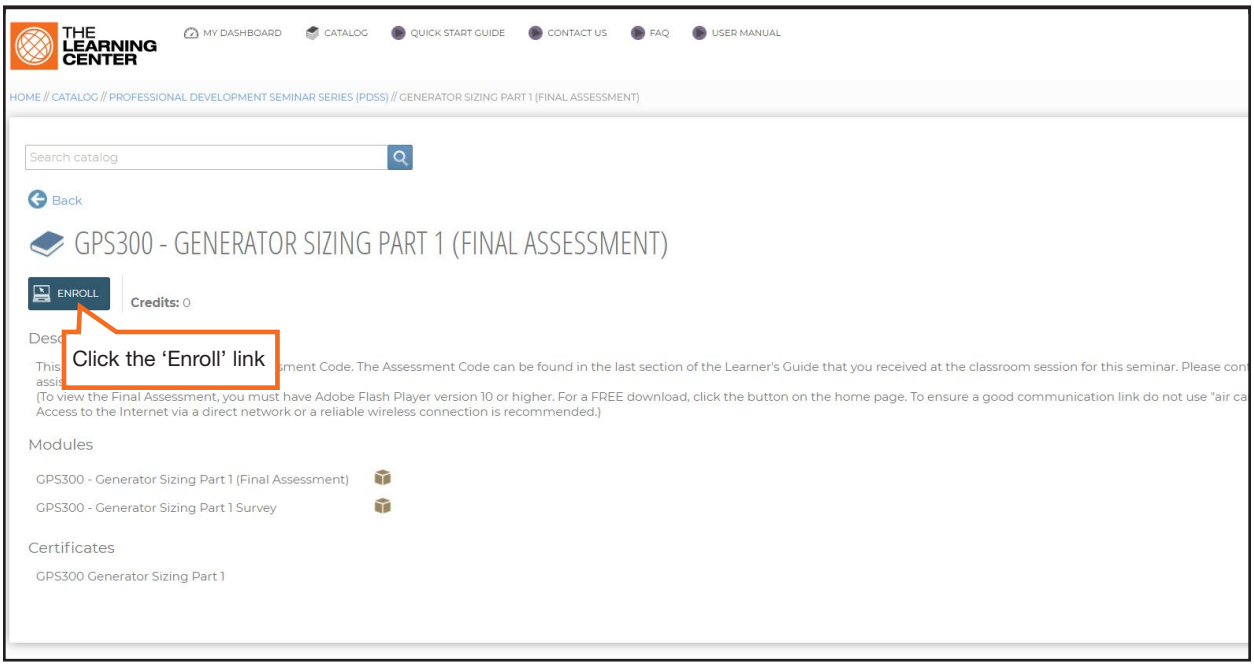


This next screen lists all currently available final assessments. Click on the final assessment that is tied to the course name and number you completed.

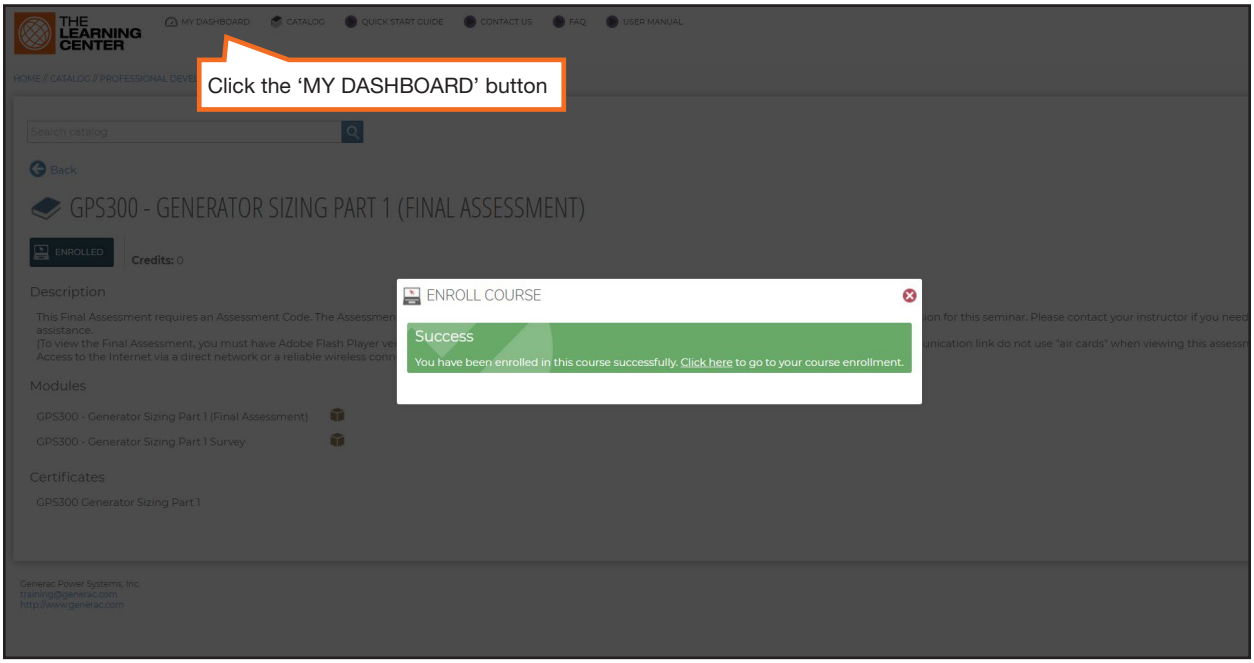


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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

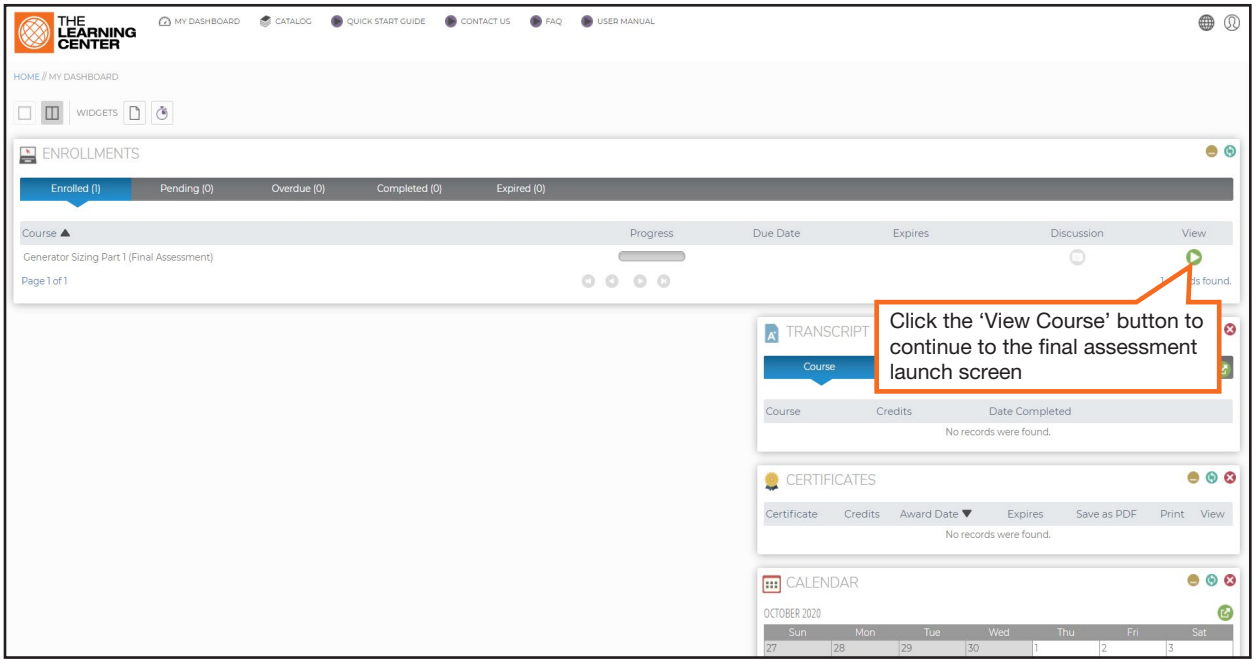


This screen confirms your enrollment. Click the ‘My Account’ button to proceed.

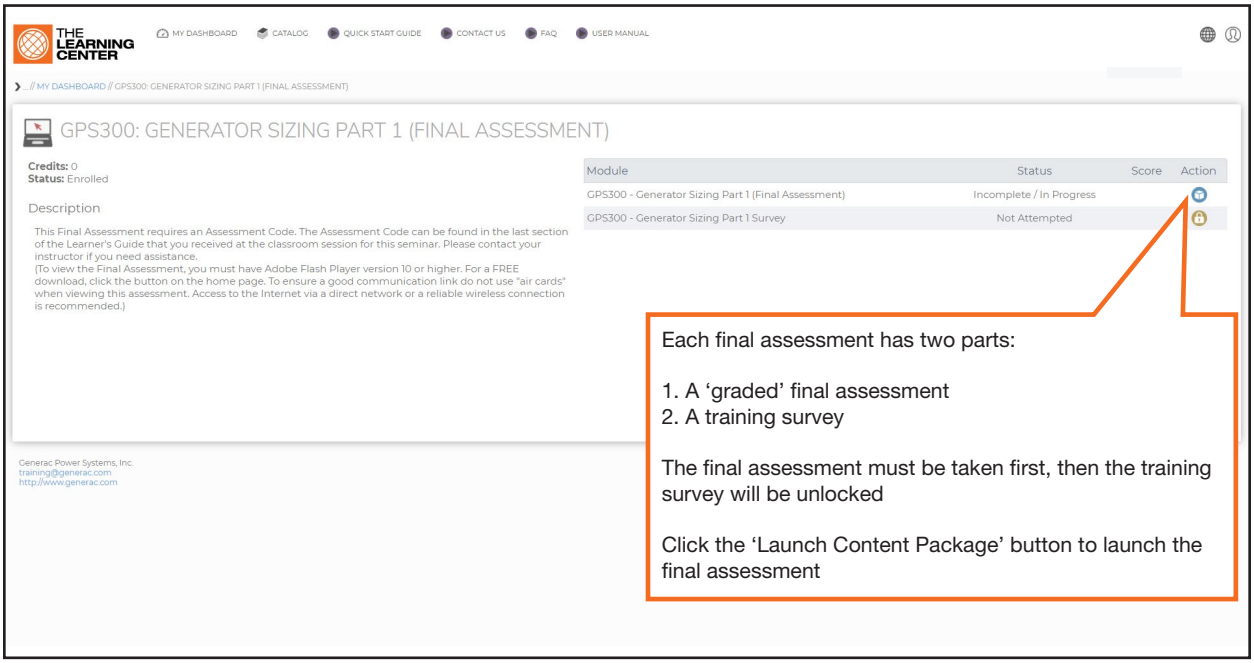


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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.

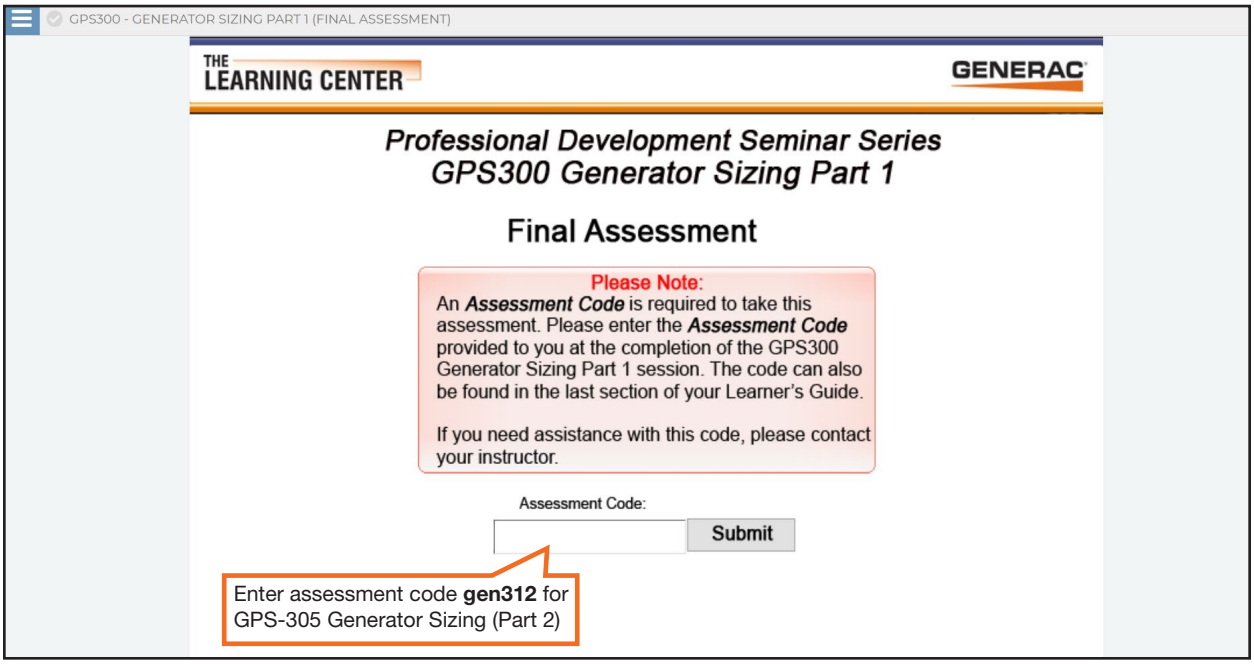


This screen lists the two parts to the final assessment. You must take the ‘graded’ assessment first, then the training survey.

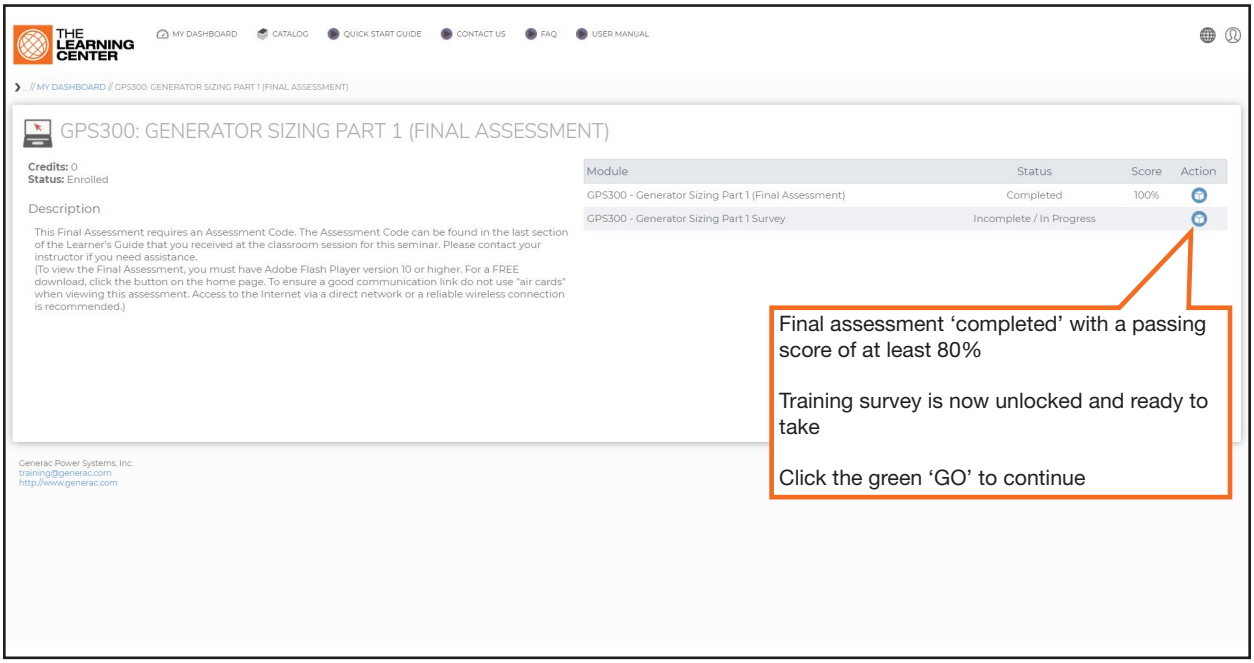


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

In the next screen an assessment code is required before you can continue. The code for GPS-305 Generator Sizing (Part 2) is **gen312**. Enter the code in the box and click the 'Submit' button to continue. From there follow the prompts to complete the 10 question assessment.

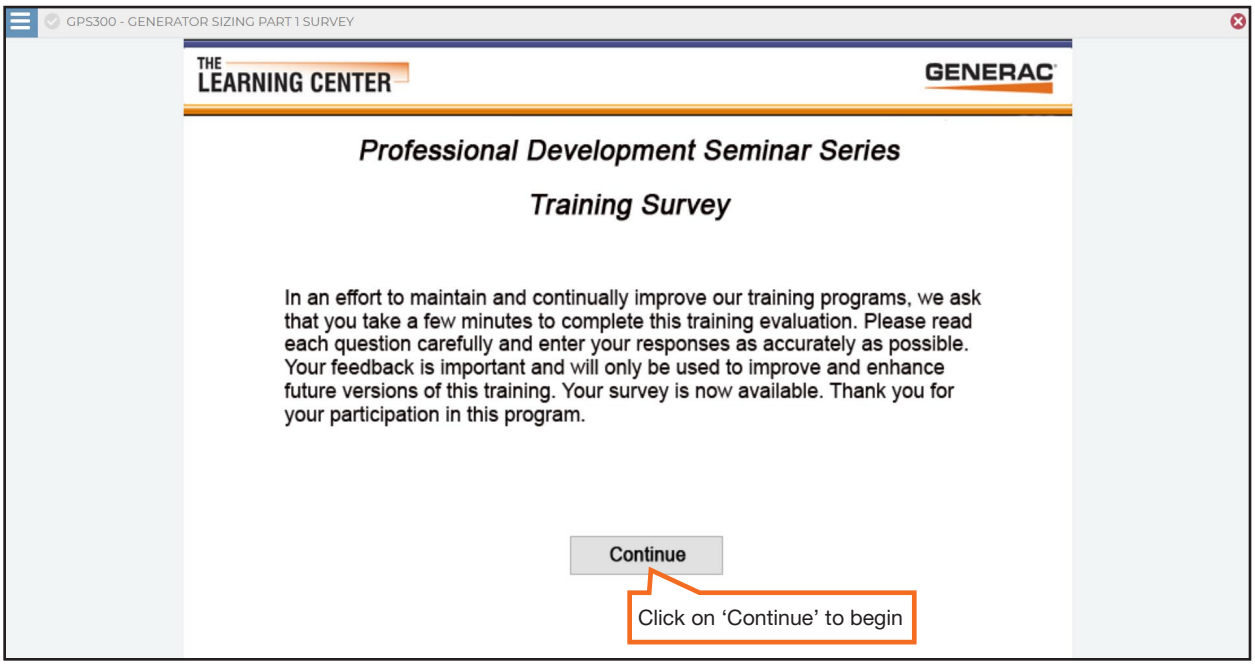


This screen will be displayed after your assessment data is saved. Note that in this example the assessment was passed with a score of 100% and the survey is unlocked and ready to launch.

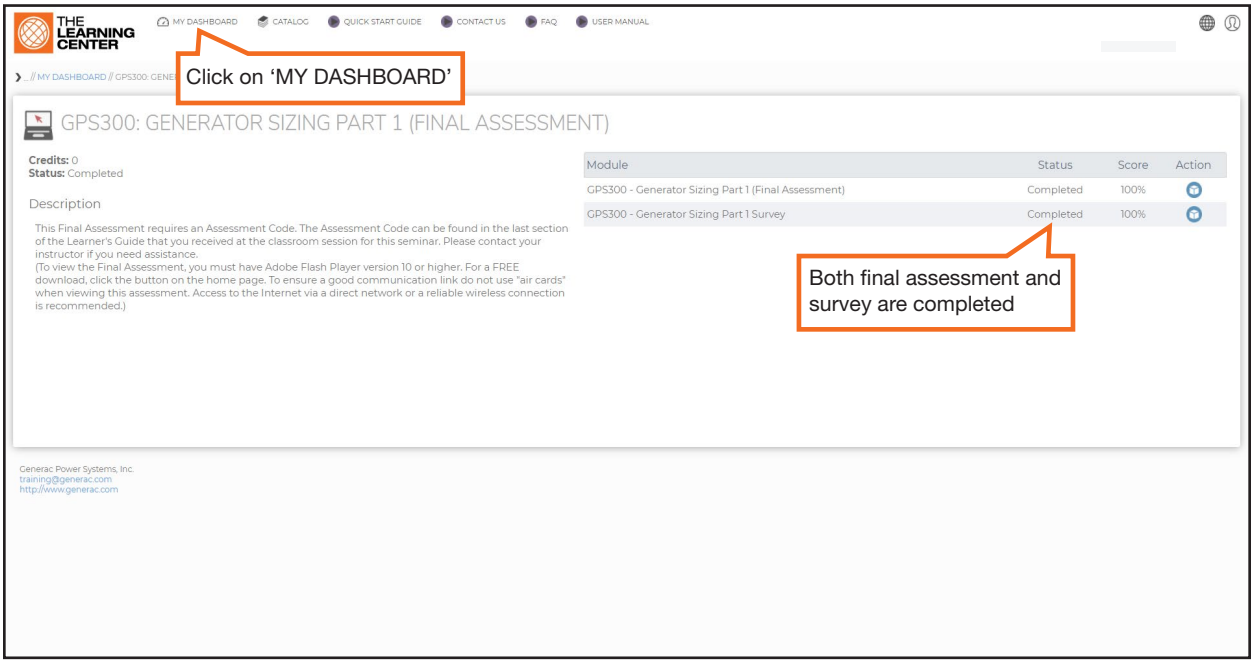


ONLINE FINAL ASSESSMENT AND CERTIFICATE REGISTRATION AND LOGIN PROCEDURE

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

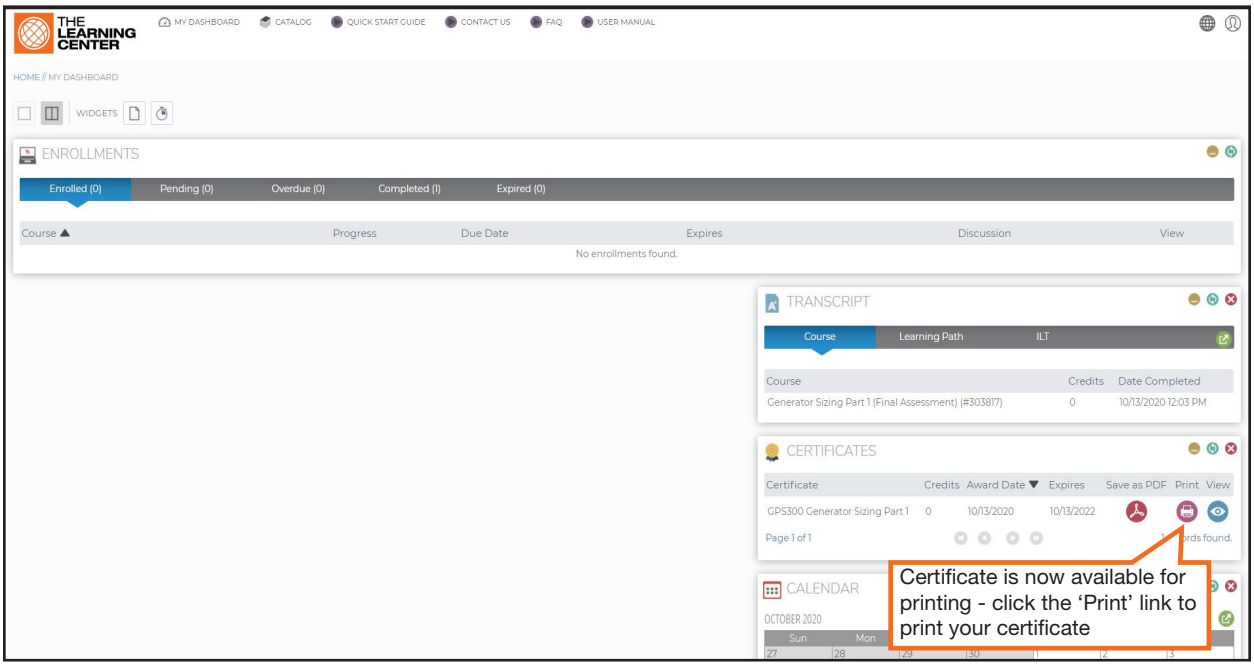


After completing the survey you will be prompted to return to the assessment menu. Your response data will be saved as before, and you will see the screen below. Click the 'MY DASHBOARD' to continue.



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



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