Hydro Generator Up Grades

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According to Wikipedia -

• **Upgrading** is the process of replacing a product with a newer version of the same product. In computing and consumer electronics an upgrade is generally a replacement of hardware, software or firmware with a newer or better version, in order to bring the system up to date or to improve its characteristics.
Hydro Generator Trends

- Life extensions
- Enhanced reliability
- Watt per water value

- Effective upgrades enable and support the above trends
Primary Hydro Generator Components for Upgrade Consideration

- Phase Rings
- Stator Slot Wedges
- Rotor Coil
  - Coil to Coil Connections
  - Turn and Ground Insulation
- Stator Winding
  - Stator Coil Insulation
  - Stator Coil design (MultiTurn VS. Roebel Bar)
  - Stator Coil Losses
- Stator Core
  - Core Lamination Steel
  - Core Lamination Coating
  - Continuous stacking (No Splits)
- Ventilation – Fans / Coolers
Phase Rings
Verifying Isolation
Completed Buss Ring Up Grade
Wedging

• Options:
  – Conventional Flat Slab
    • Less Expensive
    • More time to install properly
    • More difficult to get even compression
  – Piggy Back
    • More expensive
    • Less time to install
    • Better compression consistency
Checking Stator Wedge Tightness
Rotor Coil to Coil Connectors
Case Study #1
Coil to Coil Repair and Up Grade

- Original pole/rim design
  - Solid, bolted lead
  - Laminated rotor rim

- Problems with pole looseness and vibration due to rim warp age
Case Study #1

• Issues
  – Distorted pole mounting surface, allowing rocking of the pole
  – Uneven laminated surface coming in contact with tapered driving keys leading to false assumption of keys being driven tightly when looseness existed
Case Study #1

- **Solutions**
  - Machining of pole surface to eliminate rocking
  - Three piece key design
    - smooth driving of wedges – better seating
  - Flexible, laminated copper leads
    - Accommodates rotor and pole movement
    - Less stress
Rotor Coil Turn and Ground Insulation

• Depending upon the vintage, Asbestos containing materials may be present and need properly removed and abated

• New materials have upgraded thermal properties upgraded from Class B (130 deg. C) to Class F (155 deg. C)

• New materials also:
  – upgrade mechanical properties
  – upgrade dielectric properties
Field Coil Reinsulation

- Copper conductor is reused
- Field pole is reused
- Older asbestos containing class B insulation is replaced
- New class F insulation:
  - Turn to turn insulation
  - Coil to pole ground wall insulation
  - Coil collars
- New leads and possible design upgrade of the coil to coil connector may also be considered
Hydro Pole Up Grade

Case Study #2
Case Study #2
Hydro Pole Up Grade

• Scope – Complete field pole refurbishment

• 60 Poles; 30 Turns per pole

• 995 lbs. per pole
Poles – As Received

• Numerous Issues:
  – Bent and distorted components
    • Bowed Poles
    • Distorted end laminations
  – Broken Components
    • Immortisuer components
    • Cracked bars
    • Shorting rings
Bent Components
Bent Components cont.
Bent Components cont.
Bowed Pole Core
Bent Components cont.
Distorted Pole End Laminations
Broken Components
Broken Components cont.

Immourisuer Repair
Completed Pole Assembly

#33
Final Mechanical Check
Final Mechanical Check cont.
Stator Trends
UP Grade – Up Rate

• Older windings at or nearing end of life

• Newer and older vintage units being considered for uprate

• Reliability enhancements
Up Grade / Up Rate
Stator Rewind Considerations

• Up Grade - VS. - Up Rate?
• Stator Core
  – Existing Core Condition
  – Relation to Coil Options
  – Options and advantages or redesign
    (# of slots and steel type)
• Stator Coil
  – Improved materials and processes
  – Design that minimizes losses
  – Multi Turn - VS. - Roebel Bar?
Hydro Stator Coil Options

Multi-Turn Coil

Roebel Bars
Option Comparison

Multi Turn Coil

- Less expensive to manufacture
- Usually faster to manufacture
- Turn insulation is a common failure mode
- Less ability for uprate and loss reduction

Roebel Bar

- Eliminates the turn insulation failure mode possibility
- Improved technical ability to uprate and reduce losses
- Improved ability to maintain/repair
- More expensive to manufacture
- Usually longer delivery time
Copper Volume, Strand Size, & Arrangement Affect Losses

• $I^2R$ Losses
  – inversely proportional to copper area

• Strand/Eddy Current Losses
  – proportional to strand thickness

• Circulating Current Losses
  – voltage potential differences between strands
Leakage Flux

• Main Flux Produces E.M.F.
  – Causes current to flow through conductors
  – Bottom portion of conductor linked with maximum paths; top portion with fewer
  – Top portion of conductor has lowest A.C. impedance; bottom portion, highest
  – Inequity between the two causes “skin effect” and extra losses known as strand losses
Leakage Flux

Fig. 1. Flux leakage lines around a conductor in the stator are denser at the bottom of the slot. This gives rise to an effectively lower conductor impedance at the surface than at the base.
Transpositions in A.C. Windings

• Generally used on large high voltage generator windings.
• Number of turns is seldom more than 6 turns per coil.
• Turns consist of numerous strands

The purpose of transpositions is to reduce the A.C. circulating losses of the windings.
Losses

• D.C. $I^2R$ Losses
  – RMS ampere of A.C. has same heating effect as one ampere of D.C.

• Eddy Current Losses
  – Reduced by making strands thinner, but each strand must be insulated

• Circulating Current Losses
  – Results from potential difference between strands
Types of Transpositions

**Fig. 2.** A coil with the last half turn only inverted at the connection end.

**Fig. 4.** A simple Roebel arrangement, showing the transposition of strands.
Multi Turn Coil Twist Transposition
Roebel Transposition

- Transposition Changes Position of Conductors in Strand Bundle
  - $360^\circ$ - each strand crosses over to occupy each radial position in slot once, along length of core (finishing at same position it started)
  - Change in position minimizes potential differences between strands
Roebel Bar

Simple Roebel Bar Showing Transposition of Strands

Roebel Transpositions in Only These Sections
Roebel, Weave & Conductor Stack
Summary

• Upgrades, if properly planned and executed can enhance machine operation and long term reliable operation

• Up Grades and Up Rates are different in their purpose and intent

• As major maintenance, life extensions, and output increases are planned, both up grades and up rates should be carefully consider and incorporated into planning to achieve the greatest value
Questions