Pump Knowledge Workshop:
Eddy Current Technology
Theory of Operation
Performance Analysis
Application Considerations

Presented by:
Gary Patterson
Pump, Fan & Compressor Technical Sales Director
DSI/Dynamatic
- Constant Speed Motor, full voltage and frequency
- Sized for maximum pump horsepower and speed
- Motor Starter: Soft Start or Full Voltage

- Rigid Cast or Fabricated Frame
- NEMA P-Base Flange
- Optional High Ring Base for Vertical Units
- Constant Speed Motor, full voltage and frequency
- Sized for maximum pump horsepower and speed
- Motor Starter: Soft Start or Full Voltage

Drum Member Coupled to Motor Shaft
Salient Pole Electro-Magnetic Output Rotor

Separate Shaft

Coils: Alternating N-S polarity

Magnetic Flux Induces Torque in Air Gap

Slip rings and carbon brushes
Horizontal Coupled units will have outboard input-end bearing to support Drum Member

Main Thrust Bearing
Grease or Oil Lube
Antifriction or Kingsbury Type

Pilot Bearing
Grease Lubricated
Speed Feedback
- AC Tachometer
- DC Tachometer
- Proximity Pulse Pickup
DC Excitation Controller
- Power Consumption Approx. 1%
- Can be Enclosed or Furnished Open-Chassis for Retrofit
- Power from Motor Circuit or Separate Panel
- Remote Operation from Manual or Automated Source Signal
DC Exciter-Controller with digital control platform

- Compact size
- Magnetic pulse pickup and AC or DC tachometer inputs
- Better than 0.5% speed regulation
- Keypad monitoring of two selectable variables
- Remote monitoring for any variables
- 4 programmable Run Presets accessible locally and remotely
- Digital logic circuit with rugged SCR power conversion for DC excitation
- PLC and SCADA compatible
- Ethernet IP communication link
Efficiency Comparison

Published

Empirical Data

- ECD eff'\text{y}
- VFD pub. eff'\text{y}

- VFD
- Eddy Current

KW Usage vs % Speed

Percent Speed

% Speed
Let’s begin by examining the effect of reduced speed on centrifugal fan and pump loads. In this “ideal affinity law” instance, the load is reduced in proportion to the cube of the speed reduction. This load reduction is usually the reason for choosing variable speed in the first place. When this efficiency is applied to this reduced load, the LOSSES in the eddy current drive are as shown.

Note that maximum slip loss is at 33% slip, at which it is only 16.2% of the load input.
In fact, most pumps don’t behave exactly according to the ideal affinity curve. Many systems have static head or the process requires a minimum flow that limit the speed reduction of the pump. If we look at an example where there is static head in the system as shown here, the pump only achieves flow at 80% pump speed.

At this point, the discharge valve can be opened, and the pump will operate only between the zero flow point and maximum flow, usually at “full speed”.

Efficiency at Practical Speed
Efficiency at Practical Speed

Evaluation is inconsequential at speeds below the zero flow point, so let’s only consider the performance from 80% to 100% speed.

The next slide shows this same data with the horizontal axis expanded from 0 to 100% flow…
Efficiency vs. Losses

Here’s the same data, displayed on an expanded horizontal axis, which is renamed “Percent Flow”.

Between zero and full flow, the percent flow is approximately proportional to speed. By expanding the axis, we get a closer look at the comparative losses.

Remember that the power company bills for Kilowatthours, not “efficiency”.

[Graph showing efficiency vs. losses with annotations]

Here’s the same data, displayed on an expanded horizontal axis, which is renamed “Percent Flow”.

Between zero and full flow, the percent flow is approximately proportional to speed. By expanding the axis, we get a closer look at the comparative losses.

Remember that the power company bills for Kilowatthours, not “efficiency”.

[Graph showing efficiency vs. losses with annotations]
# Project Input Data Sheet

## Customer Information

- **Project Name:** Hi Demo Example
- **Address:**
- **City, State, Zip:**
- **Contact:**
- **Phone Number:**
- **Fax:**
- **Email:**
- **Cell:**
- **Engineer:**
- **Contact:**

## Equipment Information

- **Equipment Type:** Pump
- **Flow Control:** Throttled Valve
- **Life Cycle In Years:** 30
- **Run Time per day (hrs):** 12
- **Days per week:** 7
- **Weeks per year:** 52

## Energy Information

- **Energy Utility Name:** PG&E
- **Cost per kWh:** .08
- **Alternate Rate:**
- **Demand Charge:**

## Project Additional Costs:

<table>
<thead>
<tr>
<th></th>
<th>ECD</th>
<th>VFD</th>
<th>wA/C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Cost</td>
<td>$175,000</td>
<td>$215,000</td>
<td>$265,000</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>$40,000</td>
<td>$40,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Spare Parts Cost</td>
<td>$10,000</td>
<td>$30,000</td>
<td>$40,000</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>$1500/yr</td>
<td>$1500/yr</td>
<td>$1500/yr</td>
</tr>
<tr>
<td>Maintenance Cost</td>
<td>$1500/yr</td>
<td>$5000/yr</td>
<td>$5000/yr</td>
</tr>
<tr>
<td>Down Time Cost</td>
<td>$1500/yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Cost</td>
<td>$10,000</td>
<td>$15,000</td>
<td>$20,000</td>
</tr>
</tbody>
</table>
Life Cycle Cost Comparator

Customer Information

<table>
<thead>
<tr>
<th>Project</th>
<th>HI Demo Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company</td>
<td></td>
</tr>
<tr>
<td>Street</td>
<td></td>
</tr>
<tr>
<td>City</td>
<td>Annapolis,</td>
</tr>
<tr>
<td>Contact</td>
<td></td>
</tr>
<tr>
<td>Phone</td>
<td></td>
</tr>
<tr>
<td>Email</td>
<td></td>
</tr>
<tr>
<td>State</td>
<td>MD</td>
</tr>
<tr>
<td>Zip</td>
<td></td>
</tr>
</tbody>
</table>

Utility Information

<table>
<thead>
<tr>
<th>Name of Utility</th>
<th>B G&amp;E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Rate</td>
<td>$ 0.08</td>
</tr>
<tr>
<td>Alternate Rate</td>
<td></td>
</tr>
<tr>
<td>Demand Charge</td>
<td></td>
</tr>
</tbody>
</table>

Enter Customer Data in Green Cells
Calculated data appears in Blue Cells
Duty Cycle and Energy Comparison

**System Data**
- **Name**: HI Webinar Example
- **Type**: Pump
- **Flow Control**: Throttle
- **Life Cycle Analysis**: 30 years [Default is 40]

**Motor Data**
- **HP**: 500
- **RPM**: 900
- **Max. RPM**: 885
- **FL Efficiency**: 94.2%
- **Volts**: 4160

**Driven Load Data**
- **BHP**: 475 [Default is 95% of HP]
- **Min. speed**: 62 [% Default is 75%]

**Drive and Installation Data**
- **Drive Selection**: ECD
- **Drive Cost**: $150,000
- **Install Cost**: $20,000
- **Rebates**: $ - $ - $ -
- **Net Cost**: $170,000 $ - $ -
- **Δ Cost**: $170,000 $ - $ -

**Hours of Operation**
- **Hours per Day**: 12
- **Days per Week**: 7
- **Weeks per Yr.**: 52

**Incentive**
- **Utility Rebate**
- **One Time**: $ -
- **Annual**: $ -

**Summary of Energy Results**

<table>
<thead>
<tr>
<th>Type</th>
<th>kWh/yr/yr</th>
<th>Energy $/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECD</td>
<td>1,345,935</td>
<td>$ 107,675</td>
</tr>
<tr>
<td>Valve Control</td>
<td>1,560,031</td>
<td>$ 124,802</td>
</tr>
<tr>
<td>Annual Saving</td>
<td>214,096</td>
<td>$ 17,128</td>
</tr>
</tbody>
</table>

**Duty Cycle**

<table>
<thead>
<tr>
<th>Flow</th>
<th>% Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>20%</td>
<td>0%</td>
</tr>
<tr>
<td>30%</td>
<td>0%</td>
</tr>
<tr>
<td>40%</td>
<td>0%</td>
</tr>
<tr>
<td>50%</td>
<td>5%</td>
</tr>
<tr>
<td>60%</td>
<td>15%</td>
</tr>
<tr>
<td>70%</td>
<td>30%</td>
</tr>
<tr>
<td>80%</td>
<td>30%</td>
</tr>
<tr>
<td>90%</td>
<td>15%</td>
</tr>
<tr>
<td>100%</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Flow, not RPM!**

Total must = 100

Flow, not RPM!
### Lifetime Ownership Cost & ROI & Payback

**Pump Life Costs: A guide to LCC Analysis for Pumping Systems,** published 2001 by Hydraulic Institute and Europump

**Initial Capital Costs**

<table>
<thead>
<tr>
<th>Description</th>
<th>李</th>
<th>$</th>
<th>$</th>
<th>$</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Including purchase price, aux. services</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation, commissioning, training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brick/mortar mods to accommodate eqpt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated as 10% of above costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial inventory of spares</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End of life disposal (15% of Initial Cost)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Equipment Purchase**  

| Purchase | 150,000 |

**Installation Costs**  

<table>
<thead>
<tr>
<th>Cost</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ -</td>
<td></td>
</tr>
</tbody>
</table>

**Construction Costs**  

<table>
<thead>
<tr>
<th>Cost</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ -</td>
<td></td>
</tr>
</tbody>
</table>

**Decommission Cost**  

<table>
<thead>
<tr>
<th>Cost</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ -</td>
<td></td>
</tr>
</tbody>
</table>

**Total Initial Cost**  

| Cost    | 209,500 |

### Annual Costs

#### From System Info results x years of service

- Energy Costs  
  - $107,675  (30)  $3,230,245
- Operating Costs  
  - $1,500  (30)  $45,000
- Maintenance  
  - $2,500  (30)  $75,000

**Total Annual Costs**  

| Cost    | $111,675  (30)  $3,350,245 |

### Recurring Costs (not annual)

- Loss of production  
  - Down Time Cost  
    - $ -  (Events)  $ -
- Contamination from pumped liquid  
  - Environmental Cost  
    - $ -  (Events)  $ -
- Repairs in excess of routine maintenance  
  - Repair Cost  
    - $10,000  (Events)  $30,000
- Cost to replace failed, obsolete eqpt  
  - Eqpt Replacement  
    - $235,000  (Events)  $ -

**Total Life Cycle Costs**  

| Cost    | $3,589,745  $ -  $ -  $4,008,574 |

### ROI/Payback Calcs

- **Eddy Current Drive**
  - Total Initial Cost (investment)  
    - $136,000
  - Initial Annual Savings (Energy, Operating, Maintenance)  
    - $15,828
  - Initial Simple payback (years)  
    - 8.6
  - Initial Simple Return on Investment  
    - 11.64%

- **Throttled Valve**
  - Total Initial Cost (investment)  
    - $50,000
  - Initial Annual Savings (Energy, Operating, Maintenance)  
    - $10,000
  - Initial Simple payback (years)  
    - $6,000
  - Initial Simple Return on Investment  
    - 7,500

- **Total Life Cycle Savings**  
  - $418,830
- **Annual Return on Investment over Life Cycle (dollars)**  
  - $13,961
- **Annual Return on Investment over Life Cycle (percent)**  
  - 10.27%
Graphic Comparison

Eddy Current Drive vs. Throttled Valve

- Throttled Valve
- ECD

KWh per year Thousands

Percent Flow

10 20 30 40 50 60 70 80 90 100

1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
Ambient Air Cooling

- Like the motors that drive them, the variable speed electro-magnetic drive unit is easily cooled with ambient air.

- Losses are approximately the same as those for the motor.

- Typical locations provide an adequate volume of air to absorb and dissipate the heat load.

- No air conditioning required to maintain safe operating temperature.

- Standard design is for 40°C ambient (same as for motor).

- Higher ambient designs available.
IEEE 519-1992 “Recommended Practice”

- Motor runs across line at full voltage & frequency.
- No electronic conversion of the load power is involved.
- The exciter-controller operates at approximately 1% of the pump load.
- Harmonic distortion for the system is virtually zero.
- IEEE-519 compliance is assured without the need for analysis nor mitigation.

<table>
<thead>
<tr>
<th>Bus voltage at PCC</th>
<th>Individual voltage distortion (%)</th>
<th>Total voltage distortion THD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>69 kV and below</td>
<td>3.0</td>
<td>5.0</td>
</tr>
<tr>
<td>69.001 kV through 161 kV</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>161.001 kV and above</td>
<td>1.0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Note: High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

<table>
<thead>
<tr>
<th>Maximum harmonic current distortion in percent of IL</th>
<th>Individual harmonic order (odd harmonics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{sc}/I_L$</td>
<td>$11sh&lt;17$</td>
</tr>
<tr>
<td>$&lt;20^*$</td>
<td>4.0</td>
</tr>
<tr>
<td>20$&lt;50$</td>
<td>7.0</td>
</tr>
<tr>
<td>50$&lt;100$</td>
<td>10.0</td>
</tr>
<tr>
<td>100$&lt;1000$</td>
<td>12.0</td>
</tr>
<tr>
<td>$&gt;1000$</td>
<td>15.0</td>
</tr>
</tbody>
</table>

Even harmonics are limited to 25% of the odd harmonic limits above. Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed. * All power generation equipment is limited to these values of current distortion, regardless of actual $I_{sc}/I_L$. Where: $I_{sc}$ = maximum short-circuit current at PCC. $I_L$ = maximum demand load current (fundamental frequency component) at PCC.
No Negative Effect on Motors

- No induced harmonic voltage distortion
- No high frequency induced rotor and stator heating, shortening standard motor life
- Can use standard motors or safely retrofit existing motors without fear of damage or shortened life.
- No common-mode voltage to threaten neutral insulation.
No Induced Motor Shaft Currents

- No high frequency PWM switching to induce voltages onto the motor shaft through parasitic capacitive coupling between the stator and rotor. Such common mode shaft voltage seeks a path to ground, usually through the motors bearings.

- No need for grounding rings nor insulated bearings to mitigate shaft currents.
Standby Generator Considerations

- No-load starting eases duration of voltage sag.
- Regulators, excitation systems, and governors are unaffected (No non-linear loads involved).
- No harmonic loads to increase winding and rotor temperatures.
- No need to increase the alternator size to accommodate high harmonic loads.
Brushless Options
Brushless RT design for Large Salient Pole Drives
Brushless RT Mechanical Design

AC Excitation
Single phase
or 3 phase

Exciter Stator

Exciter Rotor

Rectifier Assembly
## Installation Considerations

### for Pump And Fan Drive Systems

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cable Length</strong></td>
<td>Up to 500 feet (transmitting only DC voltage) before requiring increase in wire size</td>
</tr>
<tr>
<td><strong>External Cooling</strong></td>
<td>Ambient air in most pumping applications</td>
</tr>
<tr>
<td><strong>Harmonic Mitigation</strong></td>
<td>Input Isolation Transformer: Up to 6KVA, 575VAC</td>
</tr>
<tr>
<td></td>
<td>Input Line Reactor: None Required</td>
</tr>
<tr>
<td></td>
<td>Output Harmonic Filters: None Required</td>
</tr>
<tr>
<td><strong>Installation Cabling</strong></td>
<td>No specialty cable requirements, only national electrical code standards apply.</td>
</tr>
<tr>
<td><strong>System Grounding</strong></td>
<td>No specialty grounding requirements, only national electrical code standards apply.</td>
</tr>
</tbody>
</table>
# Installation Comparison Considerations
for Pump And Fan Drive Systems (cont.)

<table>
<thead>
<tr>
<th>Considerations</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motor Requirements</strong></td>
<td>Standard Class F insulated, Design B motors. Specific flange and shaft details are preferred for some vertical installations.</td>
</tr>
</tbody>
</table>
| **Brand Flexibility** | Non-exclusive  
Eddy Current systems are compatible with all motor manufacturers. |
| **Bearing Protection** | None required  
Due to absence of shaft currents, no shaft grounding or insulated bearings needed. Hydraulic thrust, if any, is absorbed by the lower ECD bearing, not the motor. |
| **Anti-Reverse Ratchet** | Available Option                                                      |
Additional application considerations

- The additional length of the electromagnetic coupling in horizontal applications

- The additional height of the electromagnetic coupling in vertical applications

- Additional height and weight can reduce natural reed frequencies

- Vertical hollow shaft motors cannot be employed. (any external pump thrust is carried by an optional thrust bearing in the lower end of the electromagnetic drive.)

- Drive units have not been adapted for submersible pumps
Common Applications

**Municipal or Industrial Water & Wastewater**
- Influent Pump – Lift Stations
- Aeration Tank Pumps & Mixers
- Aeration Blowers & Compressors
- Sludge (RAS – WAS) pumps
- Effluent Pumps
- High Service, Low Service Pumps
- Anaerobic Digester Mixers
- Positive Displacement (Progressive Cavity or Rotary Lobe) Pumps

**Steam Plants (Power Generation or Central Heating/Cooling)**
- Boiler Feed Pumps
- Condensate Pumps
- Makeup Water Pumps
- Circulating Water Pumps
  - Cooling Tower or Lake
- Combustion Fans
  - Induced Draft
  - Forced Draft
- Chilled Water Circulation Pumps
Thanks for Your Attention