Digital Intelligent Artificial Lift

silverwell

Automated Interventionless Gas Lift Production Optimization – Concept to Reality
Gas Lift Production Optimization is Difficult

- Is my well completely unloaded?
- Is the well multi-point injecting?
- What is my lift depth?
- Am I optimized on gas lift?
- Can I lift deeper?
- Is my wellbore hydraulic model a good match to actual well performance?
- How much will I have to intervene?
- Do I have enough gas?
- What should be my lifting life-cycle?
Technology Opportunity

- Narrow Operating Window.
- Design safety margins.
- Injection depth limited.
- Difficult to assess lift effectiveness.
- Intervention to optimize.
- Sensitive to well dynamics.
- Multi-point injection.
- Valve Chatter
Digital Intelligent Artificial Lift - DIAL

- SOLAR POWERED
  - Low power for remote locations

- MODBUS / RTU / SCADA
  - Remote Control and Monitoring

- CHANGE GAS INJECTION WITHOUT INTERVENTION
  - Pressure, temperature and condition monitoring data

- TEC (¼ Inch)

- SURFACE CONTROL SYSTEM
  - Integrated with DIAL Control Room Software

- DIAL IN-WELL UNIT
  - Up to six actuated variable injection valves

Feb. 11 - 14, 2019
2019 Artificial Lift Strategies for Unconventional Wells Workshop
Oklahoma City, OK
Binary Actuation Technology
## Multi-faceted Business Imperative

<table>
<thead>
<tr>
<th>Optimization Feature</th>
<th>Business Benefit</th>
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<tbody>
<tr>
<td>Variable orifice size at any depth</td>
<td>Eliminate intervention</td>
</tr>
<tr>
<td>Deeper injection</td>
<td>Reduce OPEX</td>
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<tr>
<td>No deviation limitation</td>
<td>Mitigate instabilities</td>
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<td>No well intervention</td>
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<td>Reduce HSE risk</td>
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<td>Intelligent field-wide management</td>
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- Variable orifice size at any depth
- Deeper injection
- No deviation limitation
- No well intervention
- Pressure and temperature data
- Remote monitoring and control
- Intelligent field-wide management

Eliminate intervention
Reduce OPEX
Mitigate instabilities
Enhance recoveries
Optimize production
Reduce HSE risk
From Months to Minutes

DIAL-It-In™ Continuous Process

Collect  Report  Model  Review  Act
• Thailand’s largest onshore oilfield; 350km North of Bangkok
• Discovered in 1981 by Thai Shell E&P
• Fully owned and operated by PTTEP since 2004
• 150 wells currently on GL (40%)
Candidate Well Design

- Reservoir depth 2300m TVD (7550 ft)
- Reservoir pressure 2000 PSI down to 1000 PSI after 2 years
- API gravity 35
- Downhole temperature 105°C (220°F)
- GL rates required (100 to 500 Mscfd)
- Estimate production (100 to 300 bopd)
- 3 SPMs + 1 DIAL at injection depth

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<tr>
<th>Tool Type</th>
<th>Description</th>
<th>OD (mm)</th>
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<th>Length (m)</th>
<th>Top Depth (mTVD)</th>
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[Tubing Fluid Table]

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[Wellhead & X-axes Data Table]
Candidate Well Design

[Diagram showing depth vs pressure with valve combinations and tubing pressure]

<table>
<thead>
<tr>
<th>Flow Rate Designation</th>
<th>Gas Flow Rate (Mscfd)</th>
<th>V1 1.5 [4/64]</th>
<th>V2 2.5 [6/64]</th>
<th>V3 2.5 [6/64]</th>
<th>V4 3.0 [8/64]</th>
<th>V5 3.0 [8/64]</th>
<th>V6 4.0 [5/32]</th>
<th>Equivalent Size 64ths</th>
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<tr>
<td>A</td>
<td>100</td>
<td>OPEN</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>4/64ths</td>
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<tr>
<td>B</td>
<td>200</td>
<td>CLOSED</td>
<td>OPEN</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>6/64ths</td>
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<td>OPEN</td>
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<td>6/64ths</td>
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<tr>
<td>D</td>
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<td>OPEN</td>
<td>CLOSED</td>
<td>CLOSED</td>
<td>8/64ths</td>
</tr>
<tr>
<td>E</td>
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<td>CLOSED</td>
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<td>CLOSED</td>
<td>CLOSED</td>
<td>OPEN</td>
<td>11/64ths</td>
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<tr>
<td>F</td>
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<td>OPEN</td>
<td>OPEN</td>
<td>13/64ths</td>
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</table>
Installation & Commissioning

- Installation started on 4th January 2017
- RIH speed 10 joints per hour
- DIAL health check every 10 joints
- Valves closed during RIH / Opened for health checks
- Valves left open for well unloading
Benefits Observed
Well Optimization

Through downhole gauge measurement, the operator recognised the opportunity to increase gas injection rate from 400 to 500 MCFD.

Silverwell DIAL valves were opened, decreasing casing pressure.

Net Oil Production increased 10% from 217 to 239 BOPD.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Chk</th>
<th>FTHP</th>
<th>CHP_A</th>
<th>Gross Prod (bpd)</th>
<th>Net Oil Prod (bpd)</th>
<th>Gas (mscfd)</th>
<th>GL (mscfd)</th>
<th>FLP (psi)</th>
<th>Sep_P (psi)</th>
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<td>11:25:00</td>
<td>128</td>
<td>254</td>
<td>-</td>
<td>265.43</td>
<td>239.15</td>
<td>610</td>
<td>500</td>
<td>150</td>
<td>165</td>
<td>GL 500 MSCF</td>
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<tr>
<td>18/04/2017</td>
<td>07:45:00</td>
<td>128</td>
<td>251</td>
<td>-</td>
<td>252.7</td>
<td>227.68</td>
<td>596</td>
<td>500</td>
<td>150</td>
<td>165</td>
<td>GL 500 Mscfd.</td>
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<tr>
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<td>08:00:00</td>
<td>128</td>
<td>234</td>
<td>-</td>
<td>247.79</td>
<td>217.87</td>
<td>521</td>
<td>400</td>
<td>140</td>
<td>152</td>
<td>-</td>
</tr>
</tbody>
</table>
8/64th orifice size causing multi-point injection and well instability.

Upper IPO valve continuously opening and closing.

Operator increased the port size to 10/64 by opening an additional valve. Well stability achieved.

Valve closed to replicate issue and confirm the DIAL action.
In summary:

• 700 days plus of successful operations
• Approx. 120,000 barrels of oil produced
• 6 well interventions prevented
• All valves fully functional
• Pressure and Temperature sensors delivering accurate data
• Continuous well surveillance and production optimization

“The authors would like to thank PTTEP Management for the support given to pilot the technology as well as Silverwell and FK International Management who had given full cooperation and dedication in making the projects happen.”
Ground Breaking Technology in Artificial Lift: 1st Installation of Full Digital Intelligent Artificial Lift (DIAL) System at DL Field, Brownfield Offshore Malaysia

Ismail, Sy Rahim, Yahia, Elshourbagi, Ishak, Roslan, Hamat, Ben Amara, Faux, Makin

- Single string Oil Producer to complete two zones with zonal control capability & comingeld production
- 4 x DIAL units
- Contingent side-pocket mandrels for initial trial well
- DIAL sensor unit below production packer
Petronas Business Case

- Aspects of Business Value
- CAPEX SPM
- CAOEX increment – TEC, clamps
- OPEX – FGS & GLV c/o
- Deferred production
- DIAL = 1/3 to 1/4 of life-of-well cost in comparison to conventional approach

Potential DIAL vs SPM revenue generation comparison

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17
### Technology Evaluation

#### Weighted KPIs
- **Technology 25%**
- **Value Creation 30%**
- **Operations 30%**
- **HSE 15%**

<table>
<thead>
<tr>
<th>Elements</th>
<th>Target</th>
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</table>
| **Technology (25%)**
  Example:
  i. Workable or not
  ii. Technology meet design criteria for the well
  iii. Lab result | All valves is connected to the system and controls are fully functioning
  II. All Pressure & temperature sensors @ each SPM able to provide required data
  III. Valves able to function as per GLV design |
| **Value Creation (30%)**
  Example:
  i. Production gain
  ii. Cost savings
  iii. Time saving
  iv. Institutional capability | Well able to unload successfully
  II. Cost saving/time saving vs conventional SPM
  III. No. of pax development, able to control/utilize the system
  IV. Real-time GL optimization demonstrated after 3mo/6mo/1yr timeframe |
| **Operations (30%)**
  Example:
  i. NPT
  ii. Plan vs actual operation time
  iii. Production deferment | Plan installation hours vs actual installation hours
  II. Manual/Operating Guideline for the system readiness |
| **HSE (15%)**
  i. Loss time injury (LTI)
  ii. Spills/Emissions to environment | Job to be executed successfully without any injuries/HSE related |
Implementation

- April 2018
- Successful install
- May 2018
- Surface hook-up
- DCS Integration
- System “overload”
- Partial loss of communication
Failure Analysis

- Failure of PS+ pin of lower GTMS due to Electrolytic Corrosion
- Saline atmosphere trapped inside lower connector during SIT
- Presence of electrolyte with excessive power applied led to corrosion of PS+ pin
- Failure mode replicated in laboratory by submerging new GTMS sample in brine
- Need to enhance isolation of conducting areas of pins from electrolyte to prevent corrosion
Mitigation

- Epoxy Fill Protection – heat-shrink/epoxy combination to GTMS connection
- Crimp Electrical Connection Protection - Upgrade existing crimps with immersion resistant crimp-splice.
- Highly accelerated life test performed with GTMS fully submerged in brine at 125 degC and continuously powered – Reached 10 year life
In summary:

• Transparent response to issue appreciated
• Pilot program temporarily delayed – now recommenced
• Remaining true to strategic intent:
  • Raising industry standard
  • Reduced well OPEX
  • Stable production without downtime / deferrement
  • No intervention
• Extending application to dual string gas lift production

“The authors would like to thanks PETRONAS Management for the support given to pilot the technology as well as Silverwell and Neural Oilfield Management who had given full cooperation and dedication in making the projects happen.”
More production

Accelerating return-on-investment
increased well production from enhanced lift efficiency

Less intervention

Reducing opex & risk
reduced well down-time from intervention-free operation

More data

Informing production optimization
increased insight from multiple in-well sensors

Less uncertainty

Enabling management decisions
reduced misunderstanding from integrated gas lift system

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