Benefits of a System Wide Hydraulic Transient Master Plan

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Why is understanding of transients important?

- Transients occur when a pipeline system changes from one steady state to another

- Present a variety of threats to the system:
  - Structural integrity
  - Water quality of the delivered water
  - Operational budget including repair and leakage costs
  - Hydraulic performance

- Need for improved understanding of transient implications on water system
  - Reduce risk
  - Improve sustainability
Typical Transient Analysis Approaches

- Usually need-based for specific infrastructure design

- Transient planning often limited to:
  - No transient analysis
  - Request to “do some quick runs” at the 90% design stage
  - Simplified ‘rule of thumb’ analysis
  - ‘Forensic’ analysis following recurring problems or failure

- Many of these approaches fail to treat the system as a whole
  - Scope often limited to specific works under design
Typical Transient Analysis Approaches

Some of these typical approaches can result in:

- Surprises at the design stage
- Inappropriate protection
- Oversized or undersized transient protection
- Improper settings
- Hydraulically inefficient pipeline profile
- Negative impact of proposed works or protection on the other areas of the system
Master Plan Transient Analysis Approach

- Highlights the need for a master plan approach to transient planning

- Benefits to a system wide analysis that are not achievable through the typical approach:
  - Defines transient issues within the entire system using a common benchmark
  - Analyzes the system as a whole to identify transient interactions within the network
  - Provides a consistent, systematic approach to transient management
  - Part of an integrated approach to the overall water system planning, engineering and operations
Master Plan Transient Analysis Approach

- Case study - Transient Master Plan - Region of Peel, west of Toronto, Ontario, Canada
  - Servicing over 1.1 million people (projected 1.6 million by 2031)
  - 236 MGD treatment capacity, proposed for upgrade to 436 MGD
  - Water pumped through 7 pressure zones via 2 water filtration plants and 12 pumping stations
  - Floating storage - 10 Reservoirs / 3 elevated tanks
  - 200 miles of transmission mains 24 - 84 inches
  - Rapid water system expansion between 2005-2015:
    - 12 new or upgraded pumping stations
    - 55 miles new transmission main >=30 inch
    - External supply agreement

With this growth comes numerous transient issues.
Benefit - Define Transient Issues within the System

- Look at ‘big picture’ of transient issues within system
- Identify areas of transient risk on a system wide scale using a common benchmark
Define Transient Issues within the System

Provides information on:

- What areas are susceptible to negative pressures under various transient conditions?
- How well protected is each pressure zone relative to other zones?
- Impact of future flows on transients within existing feeder mains
- Why is one zone more susceptible to transient related breaks?
- Are transients negatively impacting water quality within the system?
- How well maintained is existing transient protection equipment?
- Is one station more susceptible to electrical failures than others?
- How are current operations contributing to transient problems within the system?
- How well educated are Operations staff in transient issues?
Define Transient Issues within the System
Examples from Peel Region – Operator Workshops

- Workshops with Engineering and Operations staff enabled:
  - Operator education
  - Transient fundamentals - “Transient 101”
  - Incorporate transient thinking into day to day system operations
    - “What effects will our control actions have on the system?”
  - Discussion of operations procedures (SOPs)
  - Achieved better understanding of consequences and risk of operations activities
Define Transient Issues within the System  
Examples from Peel Region – Operator Workshops

- Workshops with Engineering and Operations staff enabled:  
  - Interactive – facilitate 2-way interactions to benefit all parties

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Client Engineering / Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical knowledge</td>
<td>Knowledge of where problems in system are and possible solutions</td>
</tr>
<tr>
<td>Model – identify problems with system</td>
<td>‘Reality check’ of analysis results</td>
</tr>
<tr>
<td>Experience in other systems – what is being</td>
<td>Specific experience in system – what is and has been done.</td>
</tr>
<tr>
<td>done elsewhere – industry trends</td>
<td></td>
</tr>
<tr>
<td>Recommendations on improving operation</td>
<td>Historical operations information</td>
</tr>
</tbody>
</table>
Define Transient Issues within the System
Examples from Peel Region – Transient pressure monitoring

- Monitoring and testing provided valuable data for:
  - transient performance
  - transient model validation
- Demonstrated the value of more widespread monitoring and testing
Define Transient Issues within the System

Examples from Peel Region – Water quality sampling

- Sampling of standing water in CAV chambers indicated quality equivalent to first flush surface runoff

- Potential for pathogen intrusion under negative pressure transients

- Demonstrated the need for being proactive in preventing contamination:
  - Control negative pressures
  - Improved maintenance
  - Improved chamber design
  - Regular and widespread sampling
Define Transient Issues within the System

Examples from Peel Region - Transient protection inventory / inspection

- Air valves
- Surge valves
- HACs

- Gained understanding of the state of transient protection
- Demonstrated need for increased vigilance at critical locations
- Initiated formal record keeping
- Demonstrated to decision makers importance of spending money on inspection, maintenance and developing best practices
Benefit - Analyze the System as a Whole to Account for Transient Interactions within the Network

- Most municipalities do hydraulic and water quality modeling evaluations often as part of master planning
- Can readily leverage steady state hydraulic models for system wide transient model evaluations
- Analyze transient interactions between network components:
  - Originating from multiple pumping stations servicing the same zone
  - Between large diameter transmission mains and local mains
  - Between different transmission mains
  - Between different pressure zones (e.g. booster stations)
- Effectiveness of protection within stations, transmission and distribution
Analyze the System as a Whole to Account for Transient Interactions within the Network

- Modeling answers key questions:
  - What are critical transient scenarios?
    - e.g. Global and local PF
  - Where are the problem areas? How can we protect these areas?
  - How effective is protection?
  - What is the effect of transient protection on the rest of the system?
Analyze the System as a Whole to Account for Transient Interactions within the Network

*Examples from Peel Region – Evaluation of protection strategies*
Analyze the System as a Whole to Account for Transient Interactions within the Network

Examples from Peel Region – Evaluation of protection strategies

With HAC

Existing protection

Run 5 - Scenario - Zone1 - 2031MHD_Run5; Global Power Failure; All duty pumps; Normal Operation

Herridge Reservoir
Protection - Required Protection - HAC@LPLLPS; SRV; CAV
Analyze the System as a Whole to Account for Transient Interactions within the Network

*Examples from Peel Region - Interactions between transmission / distribution*

- Interactions identified by closing zone interconnection valve at pumping station discharge
- Impact of local distribution on transient dissipation and increased breaks
- Impact on feedermain when connection is closed
Analyze the System as a Whole to Account for Transient Interactions within the Network

*Examples from Peel Region – Model evaluation*

- Enabled efficient evaluation of transient areas of concern and mitigative measures
Analyze the System as a Whole to Account for Transient Interactions within the Network

Examples from Peel Region – Model evaluation

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**Benefit - Provides a Consistent, Systematic Approach to Transient Management**

A transient analysis master plan provides a ‘Best Practices’ approach to transient management across the system:

- Establish targets for design
- System wide transient models
- Critical evaluation / comparison of protection methodologies
- Transient management hierarchy
- Protection equipment design and maintenance
- Inventory / inspection of protection assets
- Transient pressure monitoring

- Risk assessment
- Water quality sampling
- Common approach for transient modeling, analysis and design
- Facilitate operator education and training
- Establish common, improved SOPs for the system
- Holistic and yet still cost-effective program of transient protection
Provides a Consistent, Systematic Approach to Transient Management

*Examples from Peel Region - Detailed evaluation / critique of transient protection strategies*

- Which technologies are best for the system?
- How effective are different models and manufacturers?
- Problems with their use
- How are they maintained?
- Effect of improper maintenance
- Short list of applicable protection methodologies
- Design standards
  - Sizing
  - Design features
  - Redundancy
  - Settings

<table>
<thead>
<tr>
<th>ID</th>
<th>Description</th>
<th>Notes and Applicability in Peel System</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>Dampspot controls</td>
<td>Sometimes - more difficult to maintain than other dampered check valves - should be considered as a subset of the above</td>
</tr>
<tr>
<td>15</td>
<td>Pressure regulating valves</td>
<td>Never - typically requires manual operation - can be replaced by properly designed pump control</td>
</tr>
<tr>
<td>16</td>
<td>Valve bypass lines</td>
<td>Rarely - should only be used for critical large in-line valves that are regularly operated and important for system wide operation</td>
</tr>
<tr>
<td>17</td>
<td>Pump bypass lines</td>
<td>Always - should always be considered for booster stations, or at locations where the upstream pressures are greater than the downstream pressures following a transient event</td>
</tr>
<tr>
<td>18</td>
<td>Increased pump inlet</td>
<td>Sometimes - can be used as a criteria on pump selection - not justified for existing systems unless being upgraded - implications mechanical and electrical and on operating costs</td>
</tr>
<tr>
<td>19</td>
<td>Flywheels</td>
<td>Rarely - cause complications during operation and maintenance - cannot be used with certain pump types and usually decrease efficiency - ineffective on high static head systems - implications on mechanical and electrical and on operating costs</td>
</tr>
<tr>
<td>20</td>
<td>Electronic capacitors</td>
<td>Never - too new and unproven of a technology and therefore high risk</td>
</tr>
<tr>
<td>21</td>
<td>Variable speed/frequecy drives</td>
<td>Always - excellent for controlling transients caused by pump operations - no benefit against power failures - should always be used to compliment primary surge protection, even if for a single pump or two</td>
</tr>
<tr>
<td>22</td>
<td>Soft-start starters</td>
<td>Always - good protection against pump start - no benefit for pump trips or against power failure - should be used where variable frequency drives are not desired - if used, it should act to compliment primary surge protection</td>
</tr>
<tr>
<td>23</td>
<td>Stand-by power</td>
<td>Always - very difficult (and costly) to actually use to prevent power failures - should be used to improve reliability and therefore should compliment primary protection</td>
</tr>
<tr>
<td>24</td>
<td>Alternate pump drive system</td>
<td>Rarely - very complicated and expensive from an operations point of view - typically difficult to approve by the MCE, especially in residential areas - can be used to reduce/eliminate surge protection requirement during rare peak operation by applying it to a single peak only operation pump</td>
</tr>
<tr>
<td>25</td>
<td>Open surge tanks or standpipes</td>
<td>Rarely - stand-alones are never applicable as they often require excessive heights and can lead to problems in water quality and aesthetics - interlinks to, and clogging of, storage reservoirs, can be a beneficial strategy for surge control, and deserves consideration from time to time</td>
</tr>
</tbody>
</table>
Provides a Consistent, Systematic Approach to Transient Management

Examples from Peel Region - Established Transient Management Hierarchy for the system

Modify System Design – Reduce potential for transients
- Alternate pipeline route to avoid local high areas
- Modify profile – eg. lower high point using tunneling
- Smooth profile to reduce air valve requirements

Modify Transient – Reduce magnitude of transients
- Variable speed or soft starters
- Dampened check valves
- Controlled valve operation
- Controlled pump operation
- Delay restart following shutdown
- Increase pump inertia
- Stand-by power operation

Deal with Transients – Protect the system
- Floating storage
- Hydropneumatic air chambers
- Zone interconnection
- Air valves
- Pump bypass
- Surge relief / anticipator valves
- Pipe class / material selection
Provides a Consistent, Systematic Approach to Transient Management

Examples from Peel Region - Establish common, improved standard operating procedures (SOPs) for the system

Outcomes for the Peel study included end user value to both future planning and existing operations

- Developed SOPs for transient prevention / mitigation
  - Consistent guidelines for transient control - normal and emergency operations

Examples:
- Tagging crucial valves in pumping stations
- How do we revise operations with critical surge protection off-line?
- Impact of connection to local distribution system
Provides a Consistent, Systematic Approach to Transient Management

Examples from Peel Region - Transient SOPs / Inspection / Maintenance

- As a result of study - “Overall knowledge base of field staff in terms of various operations has increased dramatically where it has become part of their culture to be aware of the relationships to transients.“

- Implemented operations:
  - Valve operation speed
  - Pump starts and restarts with time delay
  - Generator testing
  - Shutdown events
  - Annual relief valve testing and set point verification; relaying this information to engineering for confirmation of proper setting
Provides a Consistent, Systematic Approach to Transient Management

Examples from Peel Region - Transient SOPs / Inspection / Maintenance

- The transient master planning project identified a list of “must get done” activities

- Example - Identify surge critical CAVs:
  - Operates as primary surge control
  - Provides secondary protection should primary protection be off line
  - Design / maintenance protocols
    - If not designed or maintained properly, will not provide intended protection
    - Can worsen transients
  - Provided a manageable list of key CAVs for prioritized inspection / maintenance
Provides a Consistent, Systematic Approach to Transient Management

*Examples from Peel Region - Developed a common methodology and standard for design level transient analysis*

- Ensured a consistent process for each design stage of capital projects
Provides a Consistent, Systematic Approach to Transient Management

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- Ensured a consistent process for each design stage of capital projects
Benefit - Part of an Integrated Approach to the Overall Water System Planning, Engineering and Operations

- Integrate results of transient analysis with other facets of water system planning and engineering
- Leverage use of other data - Integrate / correlate results of separate studies/ information / programs
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Water System Master Servicing Plan
Maintenance Management System
Watermain Condition Assessment
Rehabilitation / Replacement Needs
Operational Protocols

Transient Master Plan

Steady state hydraulic modeling
Water quality Sampling & Modeling
Part of an Integrated Approach to the Overall Water System Planning, Engineering and Operations Examples from Peel Region – Integrating with Water Master Planning

- Phasing of major protection works with planned system upgrades
- Components identified to be critical in Master Plan may require a higher level of transient protection to reduce vulnerability risk
- Capital works planning for new storage - include evaluation of benefits for transient protection

![Graph showing negative transient pressure versus floating storage](image-url)
Part of an Integrated Approach to the Overall Water System Planning, Engineering and Operations

Examples from Peel Region - Watermain condition assessment - Correlate transient model results with watermain break data

- Spatially correlate historical break records with predicted high transients to determine areas of vulnerability

- Many breaks are pressure and transient related (directly or indirectly):
  - High pressure transients
  - Negative pressure transients
  - Cyclic loading

- Input to prioritizing surge protection requirements and/or pipe replacement

- Track watermain break records before and after transient protection
Part of an Integrated Approach to the Overall Water System Planning, Engineering and Operations

Examples from Peel Region - Watermain condition assessment - Correlate transient model results with watermain break data
Part of an Integrated Approach to the Overall Water System Planning, Engineering and Operations

Examples from Peel Region – Water Quality

- **Water quality modeling** – correlate with predicted areas of low/negative pressure transients with predicted chlorine residuals / water age to ensure quality maintained at these locations

- **Sampling studies** – increase water sampling within areas of predicted low or negative pressure transients

- **Leakage studies** – correlate high leakage areas with predicted negative pressure transients to determine areas at risk of water quality contamination

- **Intrusion** – estimate intrusion of external water into watermain under negative pressure event
Typical Transient Master Plan Process

1. Define Transient Issues
2. Field Inventory
3. Water Quality Sampling
4. Transient Pressure Monitoring
5. Recommend Appropriate Transient Protection
6. Transient Model Analysis
7. Establish Transient Performance Criteria
8. Transient Model Development
9. Assessment of Transient Risk
10. Surge Protection Facility Design Standards
11. Operational, Inspection and Maintenance Recommendations

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Keys to success for transient master plan approach:

- Previous water system master plan
- Improved hydraulic and transient modeling software
- Accurate and up to date steady state water model of system
- Good system data
- Proactive engineering and operations staff – willingness to understand problems, share knowledge / information, buy into approach / solutions and be open to modifying operational protocols and transient protection strategies
Thank You

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