Masters Thesis Information Showcase
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Department: Electronics Engineering
Programme: Masters in Engineering
Specialization: Industrial Electronics

1	**Title of the Thesis** Ai-based model predictive control for leak detection and control in gas pipelines
2	**Abstract** (min 300 to 500 words) Gas pipelines are vital for reliable energy transport, yet leaks pose serious risks including safety hazards, financial losses, and environmental harm. Conventional methods for leak detection and control either rely on physics-based models with limited adaptability or on artificial intelligence (AI) techniques that treat detection and control as separate processes. This gap often results in delayed responses and reduced operational efficiency. This thesis presents an **AI-based Model Predictive Control (MPC) framework** for **integrated leak detection and control in gas pipelines**. The proposed methodology employs AI models trained on online available published Datasets, simulate dataset and SSGC Sui Southern Gas Company's pipeline data, incorporating pressure, flow rate, differential pressure and temperature variations, to identify and classify leaks in real time. These AI outputs are then embedded into the MPC optimization structure built in MATLAB-Simulink, allowing dynamic updates to constraints and control decisions in simulated model. By coupling AI-driven detection with predictive control, the framework enables rapid adjustments of operating conditions, ensuring timely mitigation of leaks. The novelty of this research lies in unifying leak detection and control within a single closed loop structure, in contrast to existing approaches that address them independently and addressing the non-linearities in time-stamped datasets effectively and efficiently. Simulation based evaluations demonstrate that the proposed framework improves detection accuracy, reduces response time, and enhances resilience under uncertain operating conditions. This study contributes a software-based solution that can be extended to industrial pipeline supervisory systems for safer and more efficient operations.
3	**Impact on SDG#___"** (min 500 words) (Please mention the impact of the relevant attained SDG) This thesis directly contributes to **Sustainable Development Goal 9**, which calls for building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation. Gas pipeline networks such as those operated by Sui Southern Gas Company (SSGC) represent critical national infrastructure, and their safe, efficient operation underpins industrial productivity, energy security, and public safety across the regions they serve. By integrating AI-based leak detection with Model Predictive Control (MPC), this work advances SDG 9 in several concrete ways. Resilient infrastructure. Pipeline leaks, if undetected or slow to mitigate, can lead to service disruptions, structural degradation, and in severe cases, catastrophic failures. The proposed

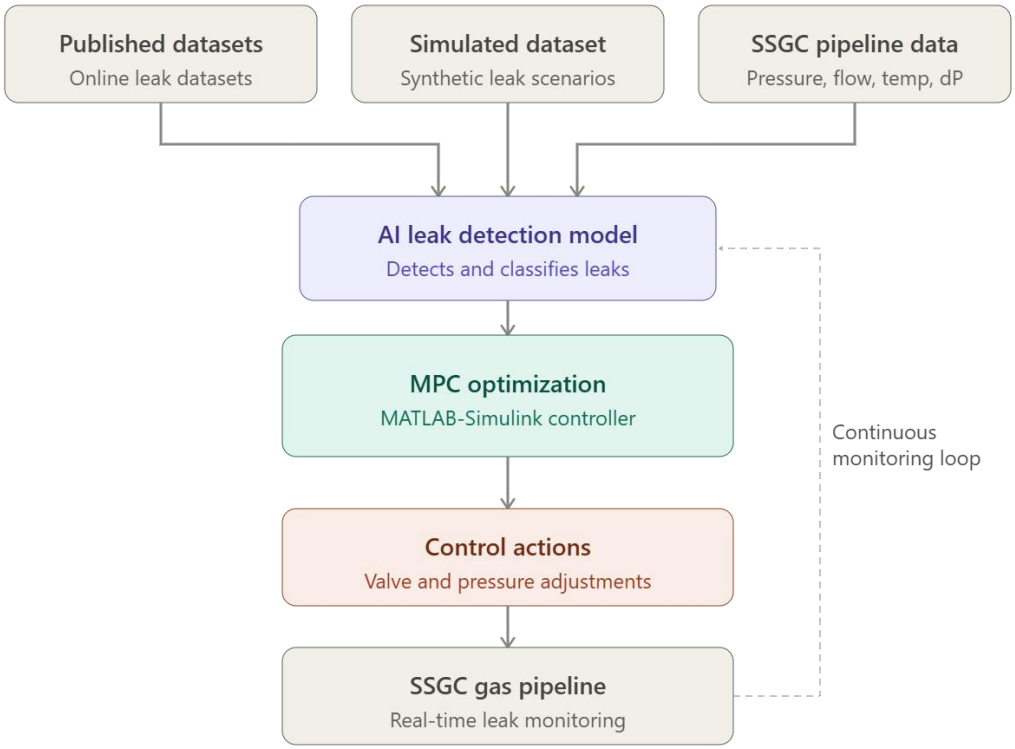
framework enables real-time identification and classification of leaks using AI models trained on both published and simulated datasets alongside actual SSGC operational data (pressure, flow rate, differential pressure, and temperature). This early-detection capability strengthens the resilience of pipeline infrastructure, reducing downtime and extending asset life by allowing operators to intervene before minor anomalies escalate into major failures.

Innovation in industrial processes. The core innovation of this thesis lies in coupling AI-driven diagnostics with an adaptive MPC optimization layer implemented in MATLAB-Simulink. Rather than treating detection and control as separate, sequential tasks, the framework embeds AI outputs directly into the control loop, allowing constraints and setpoints to update dynamically as conditions change. This represents a step toward smart, self-correcting industrial systems a hallmark of the technological upgrading that SDG 9 explicitly encourages, particularly under Target 9.4, which calls for enhanced resource-use efficiency and adoption of clean, environmentally sound technologies in industry.

Support for sustainable industrialization in a developing-economy context. Because the framework is validated using SSGC's own operational data rather than relying solely on generic or foreign datasets, it demonstrates that advanced AI-MPC techniques can be adapted to the infrastructure realities of a developing country's gas distribution network. This has practical significance: it shows a pathway for local utilities to modernize monitoring and control practices without requiring a full hardware overhaul, since the AI and control logic can, in principle, be layered onto existing SCADA and instrumentation systems.

Secondary contributions to related goals. The framework's benefits extend beyond SDG 9 alone:

- **SDG 7 (Affordable and Clean Energy):** Reducing unplanned gas losses improves the efficiency of energy delivery, helping ensure that more of the gas extracted and processed actually reaches end users rather than being lost to leakage supporting reliable, affordable energy supply.
- **SDG 12 (Responsible Consumption and Production):** Minimizing leaks reduces the wastage of a finite natural resource, aligning with the goal's emphasis on efficient use of natural resources across production and supply chains.
- **SDG 13 (Climate Action):** Natural gas is predominantly methane, a greenhouse gas with a global warming potential many times that of CO_2 over a 20-year horizon. Faster leak detection and mitigation directly reduce fugitive methane emissions, contributing even if modestly at the scale of a single distribution network to climate change mitigation efforts.
- **SDG 11 (Sustainable Cities and Communities):** Since pipeline leaks pose safety risks to nearby residential and commercial areas, improved detection and rapid control response also enhance public safety in the urban and peri-urban communities served by the pipeline network.

Taken together, the thesis illustrates how AI-enabled predictive control is not merely a technical exercise but a contribution to the broader agenda of building safer, smarter, and more sustainable industrial infrastructure directly advancing SDG 9 while generating measurable co-benefits for energy access, resource efficiency, and climate mitigation.

4	**Scholar Name** (along with contact details) Deepak Lal (EL-03/2024-25) Mobile: +92 305 5624224
5	**Supervisor & Co-supervisor Name** (along with contact details) **Dr. Tariq Rehman** **Assistant Professor** Department of Electronic Engineering NED University of Engineering and Technology-75270 Email: tariqrehman@neduet.edu.pk Mobile: +92 330 0283747
6	**Graphical Abstract**