

Nuth Otanasp, Siriwich Tadsuan, Chanintorn Chalermasuk, Traivith Chupkum,
Mathu Rajitparinya, Wanachaporn Phoplook, Suriyan Laohalertdecha and Sutamet Ridcham
Computer Engineering, Southeast Asia University, Bangkok, Thailand

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This diagram illustrates the components of the YF-S201 Flow Sensor system. The main assembly consists of a long, cylindrical pipe. A pressure transmitter is mounted on the left side of the pipe, and a mini hydro generator is mounted on the right side. A solenoid valve is shown separately, connected to the main assembly. An ESP8266 microcontroller is shown separately, connected to the pressure transmitter. The components are labeled as follows:

- ESP8266 Microcontroller** (The local brain)
- YF-S201 Flow Sensor** (Captures real-time pulse data)
- Pressure Transmitter** (Captures real-time pipe pressure)
- Mini Hydro Generator** (Harvests kinetic energy)
- Solenoid Valve** (Physical cut-off actuator)

The diagram is divided into three vertical sections by dashed lines:

- THE EDGE (PHYSICAL):** Contains a **Water Flow Turbine** and a **Pressure Gauge** on the left, both connected to an **ESP8266 Microcontroller** in the center. Below the microcontroller is an **Actuator: Solenoid Valve**, connected to the microcontroller by a red line.
- THE CLOUD (STORAGE):** Contains a **RESTful API** (diamond shape) and a **MySQL Database** (cylinder shape). The microcontroller connects to the API, which then connects to the database.
- THE INTELLIGENCE (USER):** Contains a **Predictive AI Model (MA-SD)** (brain icon) and a **Flutter Application** (phone icon). Both are connected to the MySQL Database.

REAL-TIME CONTROL

Pressure & Flow

MANUAL AUTO TIMER

**Anomaly Detected:
Automatic Shut-off
Triggered**

CONSUMPTION ANALYTICS

200 Liters

Day	Consumption (Liters)
MON	120
TUE	150
WED	220
THU	160
FRI	130
SAT	180
SUN	110

MON TUE WED THU FRI SAT SUN

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A micro-analysis of a 15-minute test window showing the system responding to active anomalies in real-time.

The graph displays pressure fluctuations over a 15-minute period. A dashed horizontal line represents the threshold. Three intervention points are marked with bullseye symbols where the pressure drops significantly below the threshold.

Time (AM)	Recorded Pressure (psi)	Intervention
7:10	~1.2	No
7:11	~1.0	No
7:12	~1.2	No
7:13	~1.0	No
7:14	~0.8	No
7:15	~1.0	No
7:16	~1.1	No
7:17	~0.5	Yes
7:18	~0.8	No
7:19	~1.1	No
7:20	~1.2	No
7:21	~1.0	No
7:22	~0.7	No
7:23	~0.9	Yes
7:24	~0.5	Yes

Accuracy: **93%**
Precision: **100%**
Recall: **67%**
F1 Score: **80%**

Recorded Pressure --- Threshold Intervention

Testing absolute measurement error of the YF-S201 sensor across **different flow intensities** using a standard 0.60L volume baseline.

Flow Rate	Mean Absolute Error (%)
30% Flow Rate	2.67%
60% Flow Rate	2.67%
100% Flow Rate	11.66%

Highly accurate under standard domestic flow rates; error margins increase only at maximum pipe capacity.

Transitioning from laboratory simulation to physical deployment revealed environmental variables that challenge the dataset.

The diagram illustrates three environmental variables that challenge the dataset, each represented by an icon and a text box. The background is a light blue grid with faint technical drawings of a compass, a clock, a circuit board, and a Wi-Fi signal.

- Baseline Masking**: Represented by a clock icon with a red needle. The text states: "Extremely low baseline pressure in testing pipes occasionally caused normal use and leaks to look identical to the AI, masking critical trends."
- Hardware Degradation**: Represented by an icon of a microcontroller with a red drop. The text states: "Moisture leakage at the Pressure Transmitter joints caused rust, skewing analog data inputs sent to the microcontroller."
- Network Dependency**: Represented by a Wi-Fi signal icon with a red slash. The text states: "Internet connectivity drops prevented data ingestion to the MySQL database, temporarily breaking the 4-week moving average calculation chain."

Aggregated performance of the Dynamic Threshold model across 105 real-world simulated events over a 7-day continuous trial.

The infographic features a background of a grid with various mathematical symbols like pi, infinity, and plus signs. On the left, the text 'Overall System Accuracy' is written in a light blue, sans-serif font. To its right, the large number '92.29%' is displayed in a bold, dark blue font. Further right, there are four white boxes with black borders arranged in a 2x2 grid. The top-left box contains the number '27' in dark blue and the text 'True Positives' below it. The top-right box contains the number '3' in red and the text 'False Positives' below it. The bottom-left box contains the number '5' in red and the text 'False Negatives' below it. The bottom-right box contains the number '70' in dark blue and the text 'True Negatives' below it.

True Positives	False Positives
27	3
False Negatives	True Negatives
5	70

The system successfully adapts its threshold minute-by-minute based on rolling historical contexts.

The diagram illustrates the components of a smart irrigation system and their interconnections. A central grey PVC pipe with three T-junctions serves as the backbone. On the left, a blue NodeMCU ESP8266-12E module is connected to the first T-junction via a black cable. Above this junction, a yellow YF-S201 Water Flow Sensor is installed, with a red line connecting it to the NodeMCU. On the right, a black Solenoid Valve & Relay is connected to the second T-junction via a black cable, with a red line also connecting it to the NodeMCU. Below the right T-junction, a white Pressure Transmitter Sensor is connected to the pipe, with a red line connecting it to the NodeMCU. The entire system is set against a light blue background with a green grid pattern.

NodeMCU ESP8266-12E
The local brain, handling C++ logic and Wi-Fi transmission.

YF-S201 Water Flow Sensor
Hall Effect sensor measuring flow rate (1-30 L/min).

Solenoid Valve & Relay
The physical actuator capable of instantly severing water flow upon NodeMCU command.

Pressure Transmitter Sensor
Analog measurement mapping real-time pressure variance (PSI).

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Component
Water Flow Pump Mini Hydro Generator Turbine.

Mechanism
Converts the kinetic energy of the flowing water directly into electrical energy during active use.

Impact
Continuously charges the central 12V battery pack. This drastically reduces maintenance overhead and external grid reliance, ensuring the system remains self-sustaining during normal operation.

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Dynamic Threshold (PSI) = MA(pressure) - SD(pressure)

The graph illustrates the dynamic threshold calculation. The Y-axis is labeled 'Pressure (PSI)' and the X-axis is labeled 'Time'. The 'Real-time Pressure' is shown as a highly volatile blue line. The 'Moving Average (MA)' is a smoother blue line that tracks the general trend of the real-time pressure. The 'MA - Standard Deviation (SD)' is represented by a light blue shaded region around the MA line, indicating the acceptable variance. The threshold is calculated as $\text{Dynamic Threshold (PSI)} = \text{MA}(\text{pressure}) - \text{SD}(\text{pressure})$.

The Logic

- Moving Average (MA)**
 calculates the expected pressure for any specific minute based on the 4-week historical baseline.
- Standard Deviation (SD)**
 calculates the acceptable variance for that minute.

The Rule

As long as real-time pressure remains inside the threshold "Tunnel", flow continues. The threshold adapts minute-by-minute to distinct user habits.

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The image displays three mobile application screens, each representing a different functional area of the software. The first screen, 'Real-Time Oversight', features two large circular gauges for 'Flow Rate' (3.5 L/min) and 'Pressure' (4.9 PSI), with a toggle for 'Auto/Manual Override' and a 'Solenoid Valve' control. The second screen, 'Predictive Scheduling', shows a calendar view for 'Current 2023' with red blocks indicating scheduled events, and a 'Clock' section for setting 'Start Time' (08:00) and 'End Time' (12:00). The third screen, 'Data & Economics', presents a bar chart of 'Average Daily Cost' over a 10-day period, with a prominent red box showing a total cost of '\$ \$34.50' and a '+5%' increase, alongside a 'Daily Cost' of '120 L'.

Real-Time Oversight
Live dials for Flow Rate and Pressure. Immediate Auto/Manual toggle overrides for the Solenoid Valve.

Predictive Scheduling
Time-based manual control. Users can set specific, operational windows, actively overriding the AI.

Data & Economics
Synthesized historical data tracking. Translates PSI and Liters directly into financial impact and monthly cost summations.