Expansion of GO-FLOW for dynamic and Living PSA applications

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GO-FLOW Methodology – Basic operator

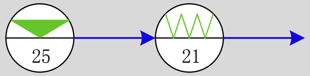
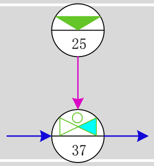
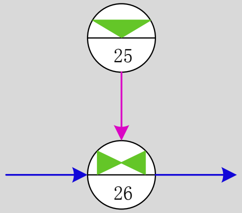
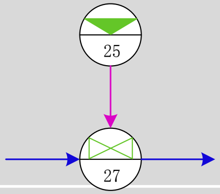
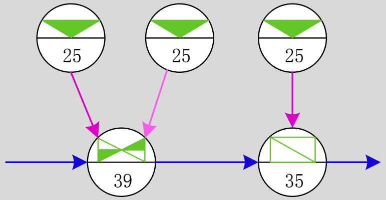
GO-FLOW methodology is a success-oriented system reliability/availability and safety analysis method for **time-dependent** and **phased-mission** system.

A total of 14 standard GO-FLOW operators are roughly classified into four categories:

- **Signal generator**
  Represent the signal sources
- **General functional operators**
  represent the failure mode of component
- **Logical generators**
  describe the logical relationship
- **Case-specific operators**
  use for specific application solution

kind	Type	shape	Name
Signal generator	25	25	Signal generator
General function operators	21	21	Two-state Component
	26	26	Normally Closed Component
	27	27	Normally Opened Component
	35	35	Operating Failure of Component
	37	37	Standby Failure of Component
	38	38	Maintenance of Component
	39	39	Opening and closing action component
Logic generators	22	OR 22	OR Gate
	23	NOT 23	NOT Gate
	30	AND 30	AND Gate
Case-specific operators	24	DIF 24	Difference operator
	28	DLY 28	Delay operator
	40	40	Phased-Mission operator

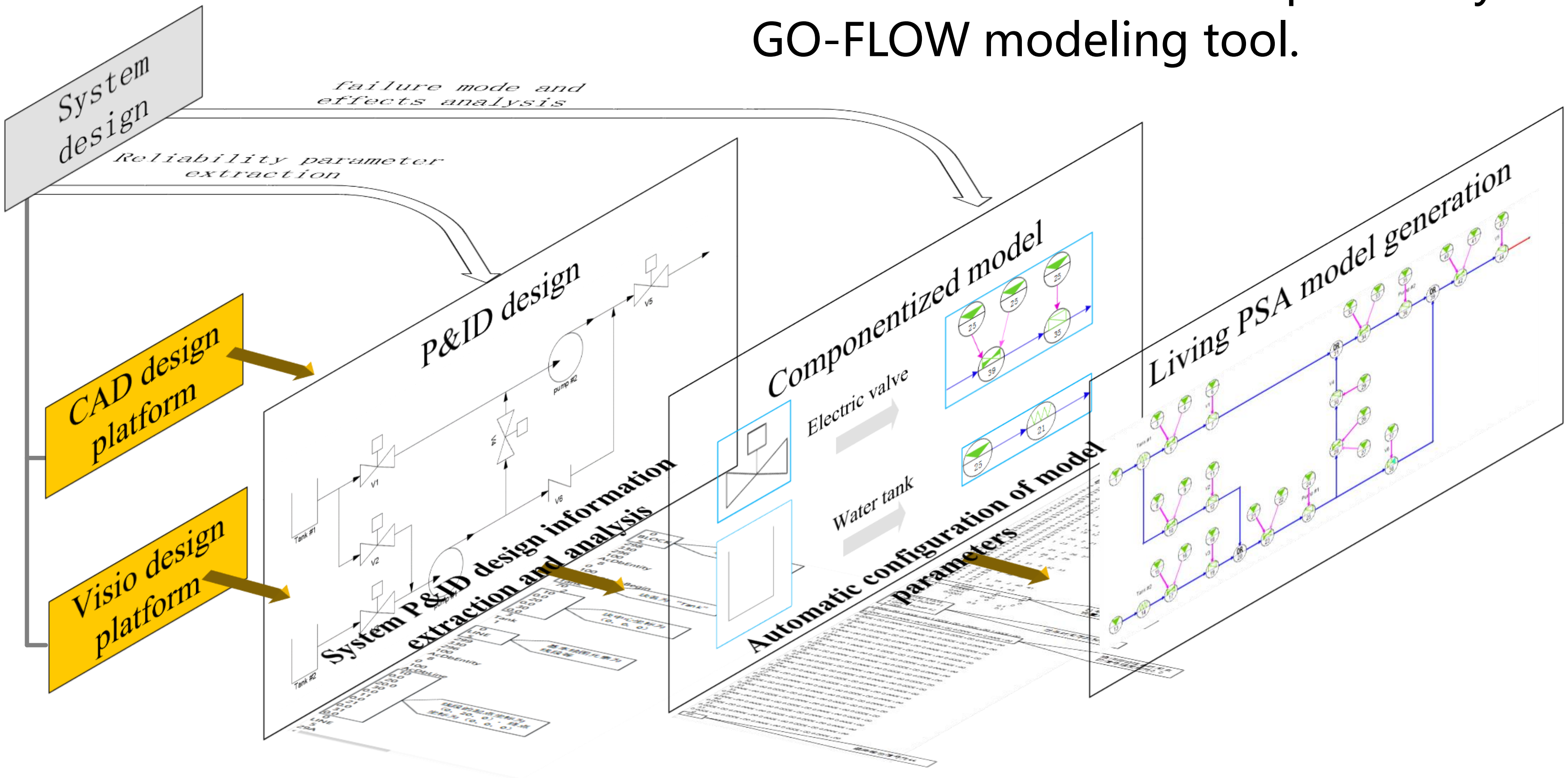
GO-FLOW Methodology – Componentization model

Categories	Sub-categories	Type of component	Failure mode	Reliability parameter	Componentized GO-FLOW model
Non-action component	Source component	container	leakage	Probability of Failure on demand P_g	
	Non-source component	Heat exchanger	Blockage, leakage	Failure rate λ Repair rate μ	
		Check valve			
Action component	Normally closed component	Relief valve Safety valve	Leakage, Fail open	Probability of action ahead of time P_p Probability of Failure on demand P_g	
		Relay	Overload, Wear out		
	Normally open component	Fuse and circuit breaker	Fail closed	Probability of action ahead of time P_p Probability of Failure on demand P_g	
	Switching component	regulating control valve	Failure on demand	Probability of action ahead of time P_p Shutdown failure P_c Startup failure P_o Failure rate λ Repair rate μ	
		pump	Failure of demand, operating failure		

Automatic Modeling – Overview of framework

- Avoid human error
- Improve modeling speed
- Map the system model correctly

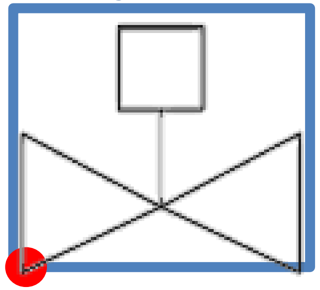
Based on the similarity of flow connection in both actual physical flows and GO-FLOW signal flows, a 'flow-based' method are used to describe the specifically customized GO-FLOW modeling tool.



Automatic Modeling – Implementation procedure

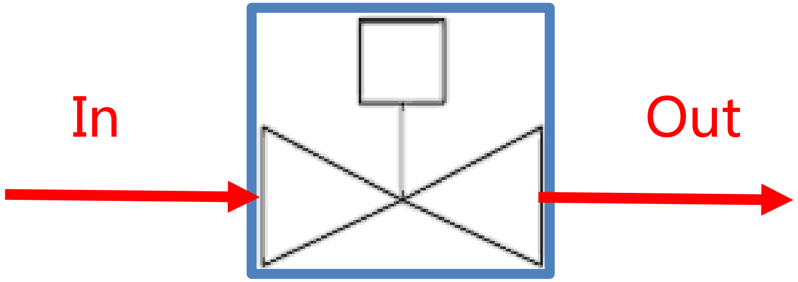
Automated GO-FLOW modeling process consists of three steps:

1.System P&ID design information extraction and analysis.



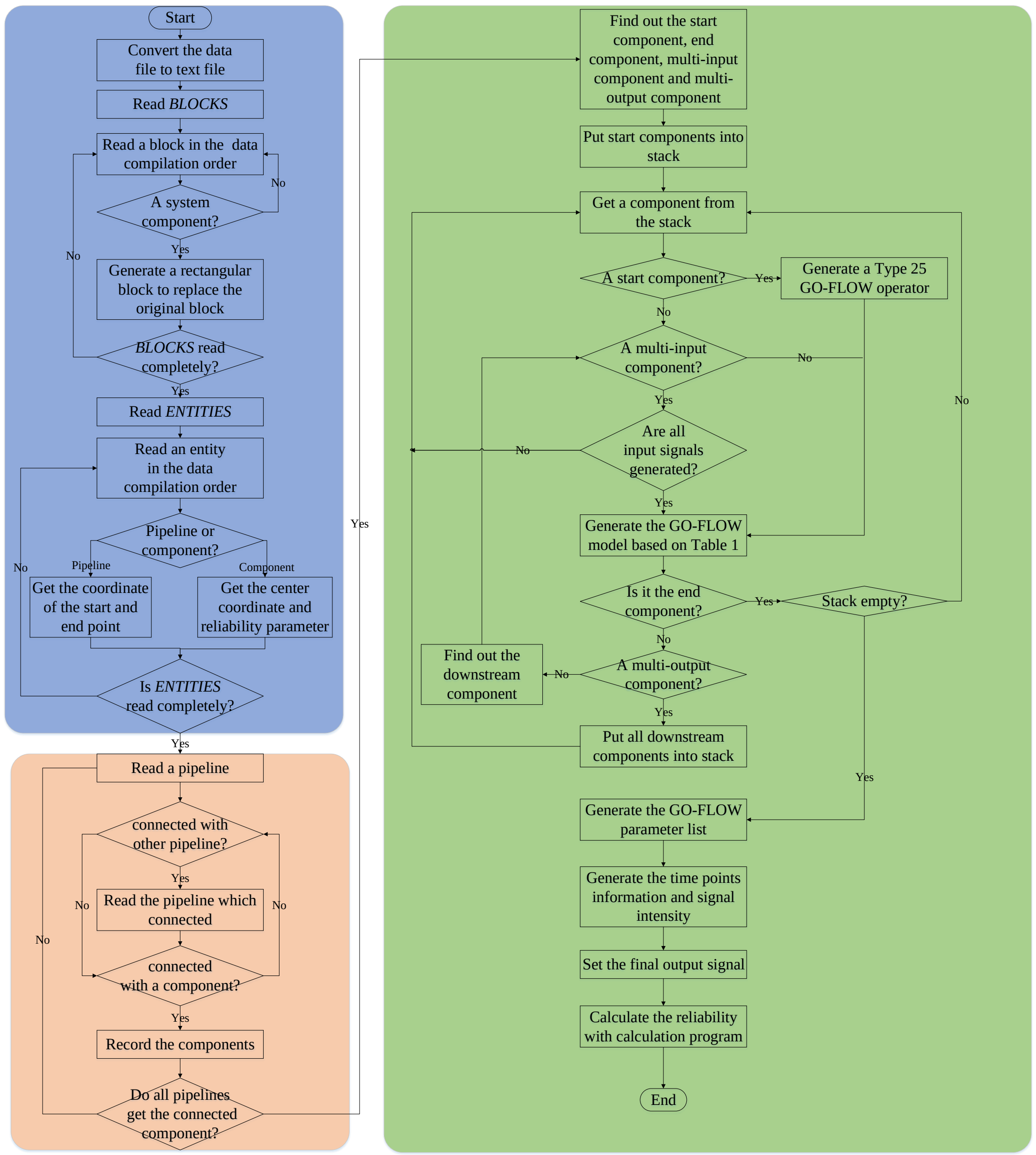
Minimum coordinate (0,0,0)
Maximum coordinate (15,20,0)

2.Connection relationship identification.



3.GO-FLOW model generation.

system structural model generation



Automatic Modeling – Case demonstration

Step 1: information extraction and analysis

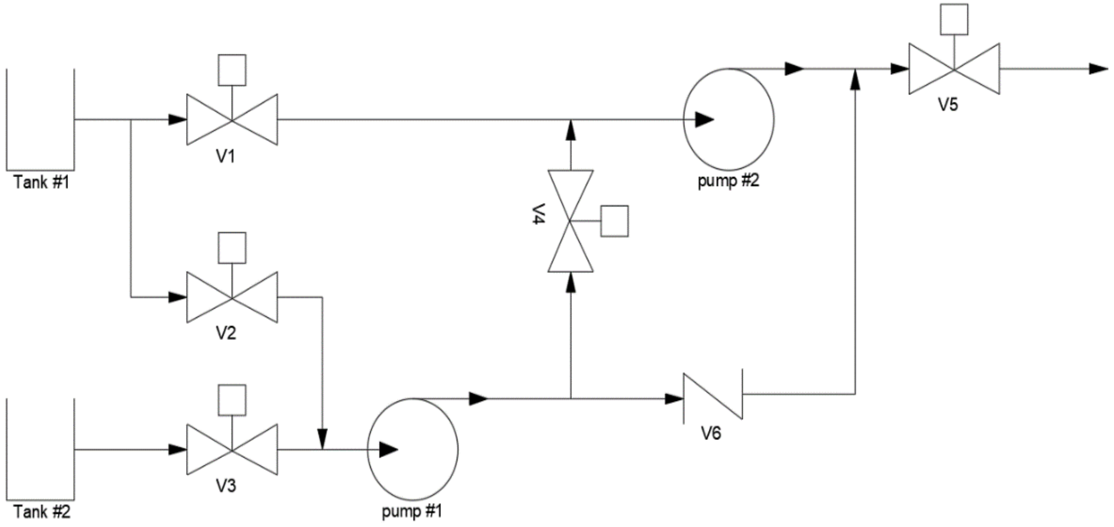
- Water storage tank
- Electric isolation valve
- Water transport pump
- Check valve

Step 2: Connection relationship identification

- Multi-input: Pump #1, Pump #2, V5
- Multi-output: Tank #1, Pump #1
- Starting component: Tank #1, Tank #2
- Ending component: V5

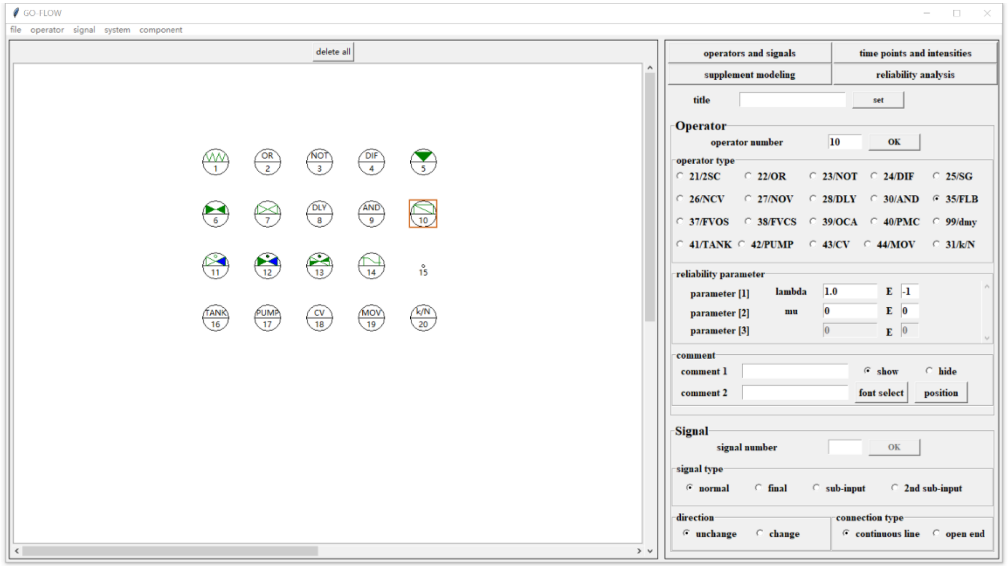
Step 3: GO-FLOW model generation

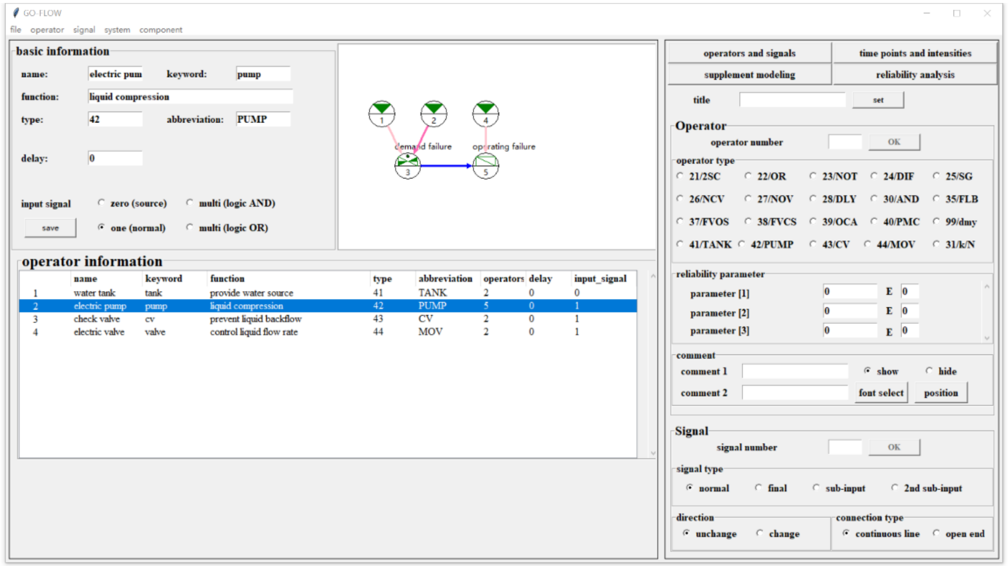
- System structural model generation
- Time series supplement

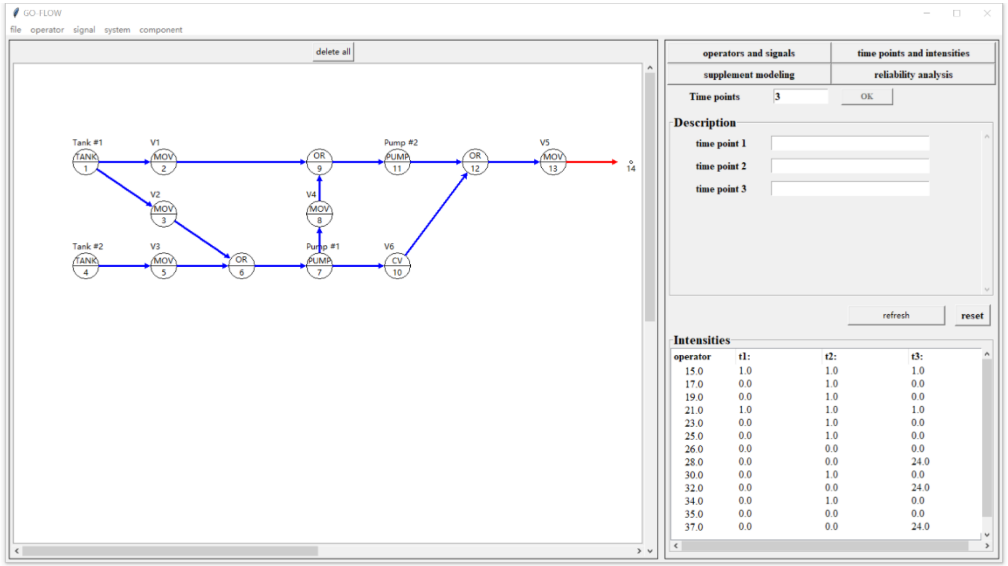


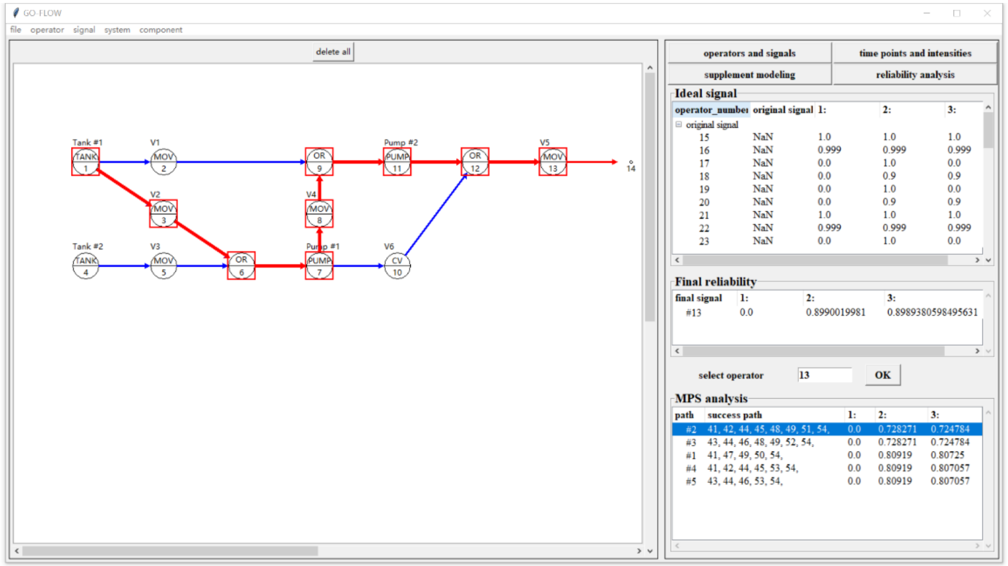
Depth-first traversal algorithm:
Tank #1 → V1 → V2 → Tank #2 → V3 → Pump #1 → V4 → Pump #2 → V6 → V5

GO-FLOW Modeling Platform for Living PSA Application

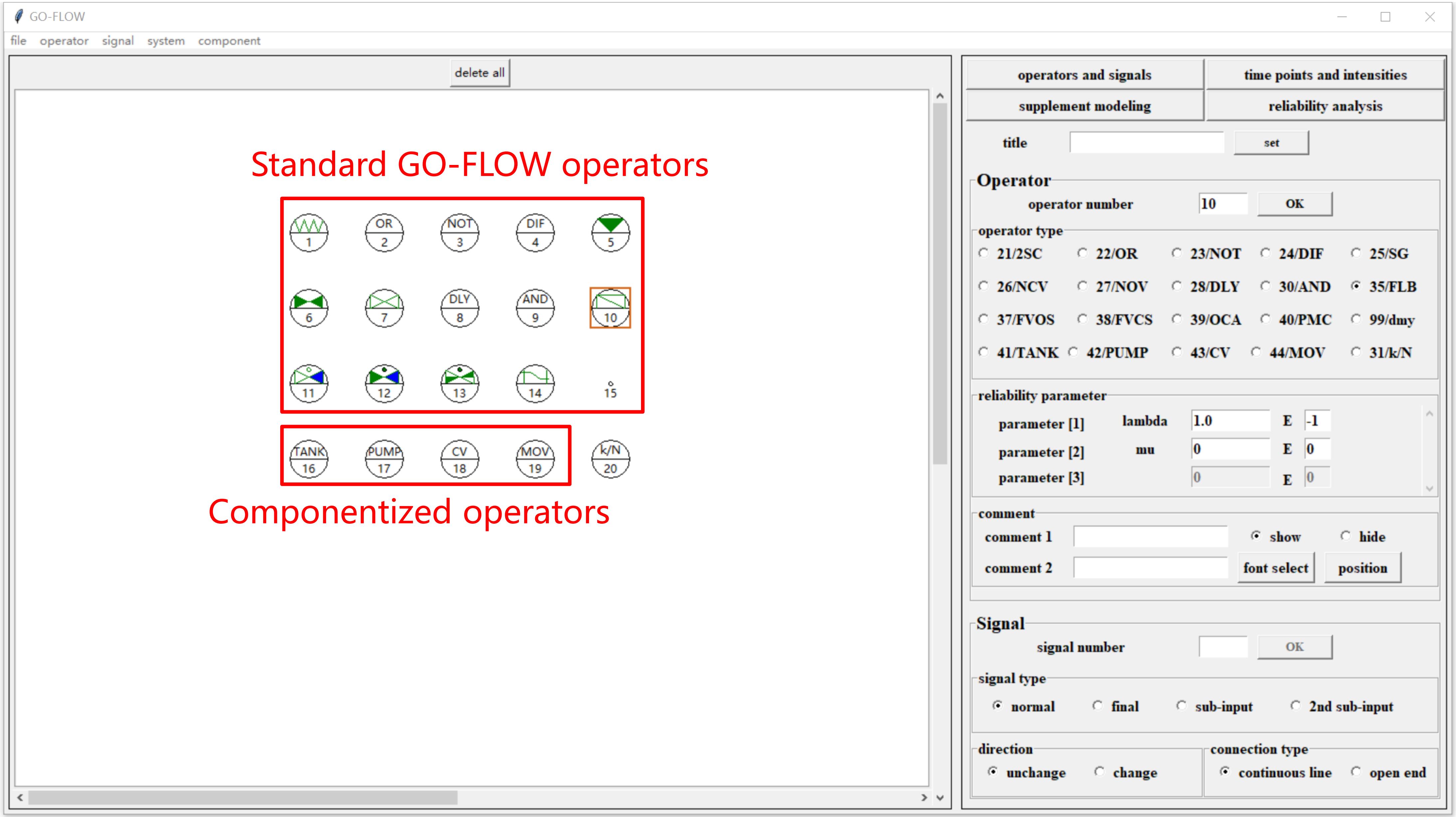




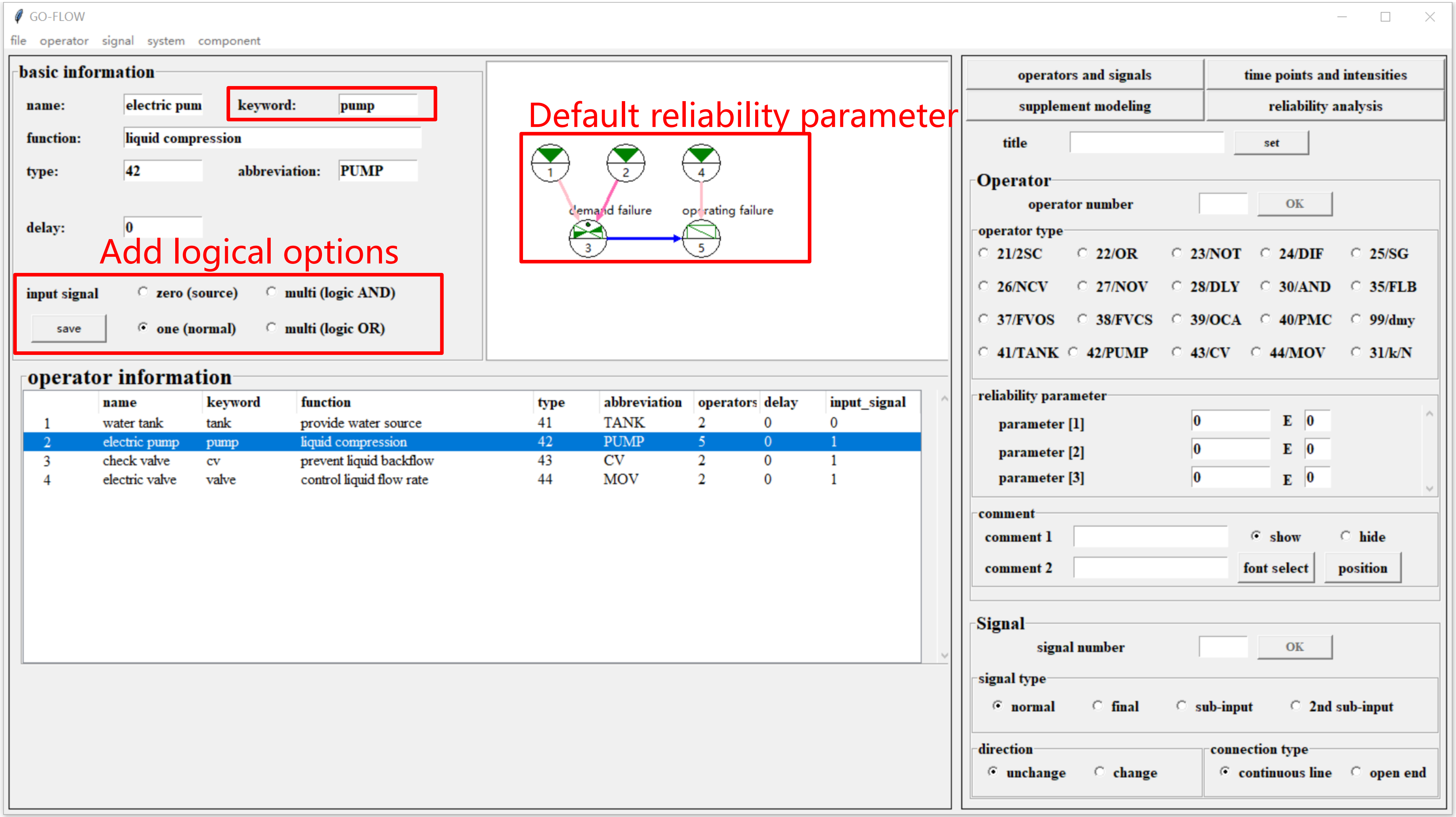




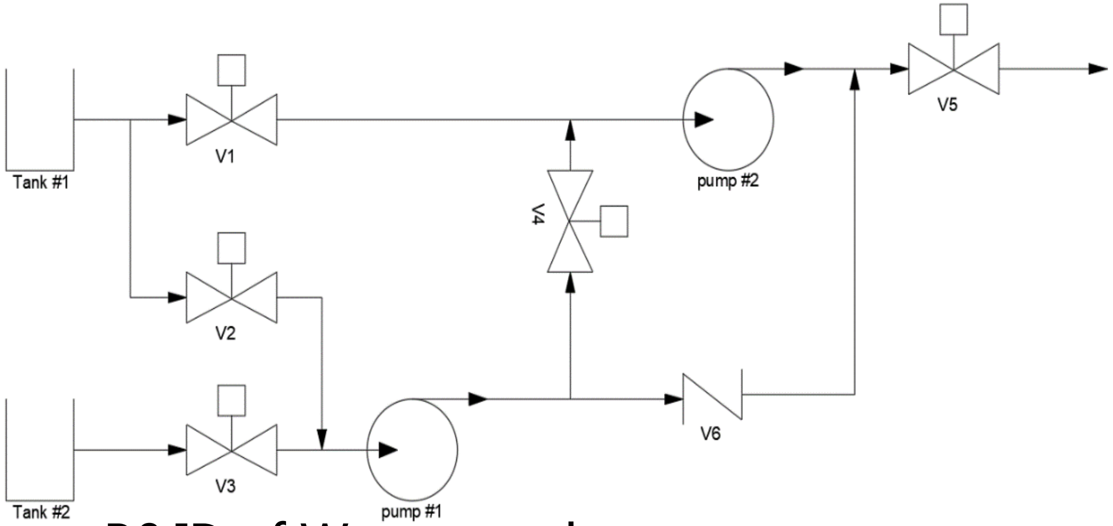
GO-FLOW Modeling Platform for Living PSA Application



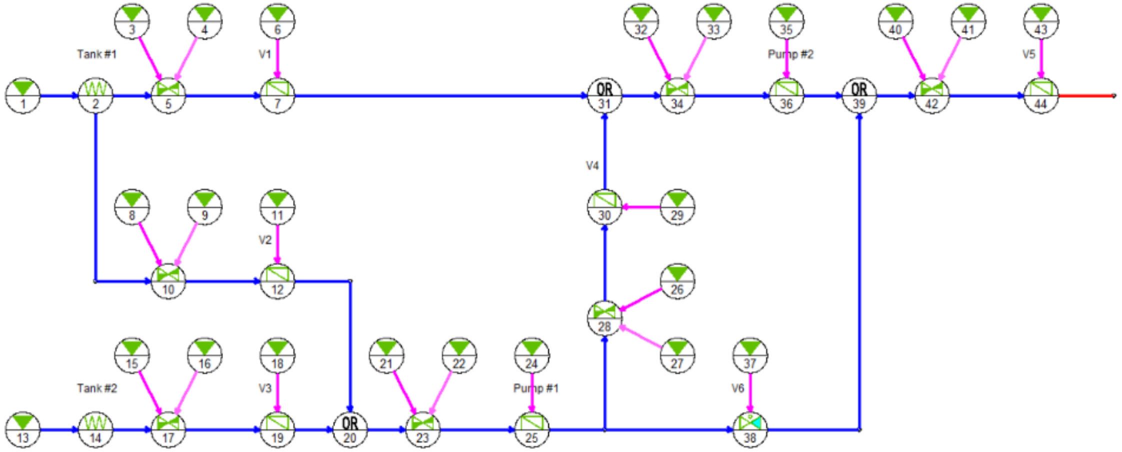
GO-FLOW Modeling Platform for Living PSA Application



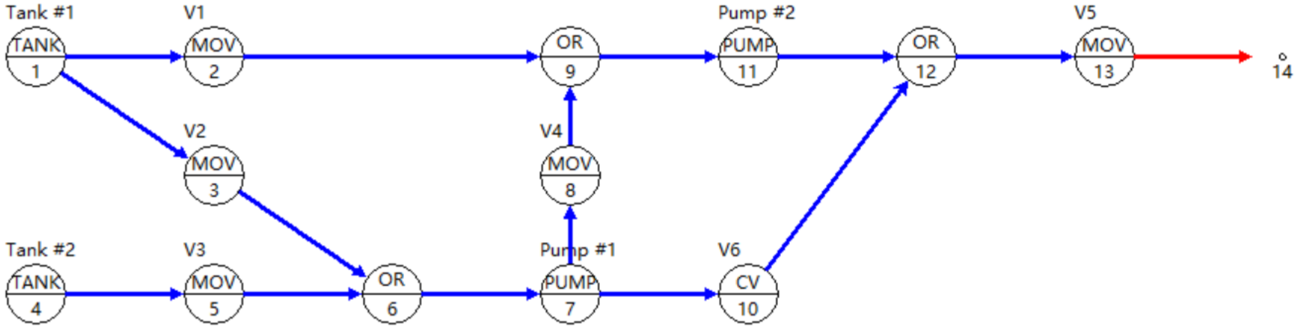
GO-FLOW Modeling Platform for Living PSA Application



P&ID of Water supply system



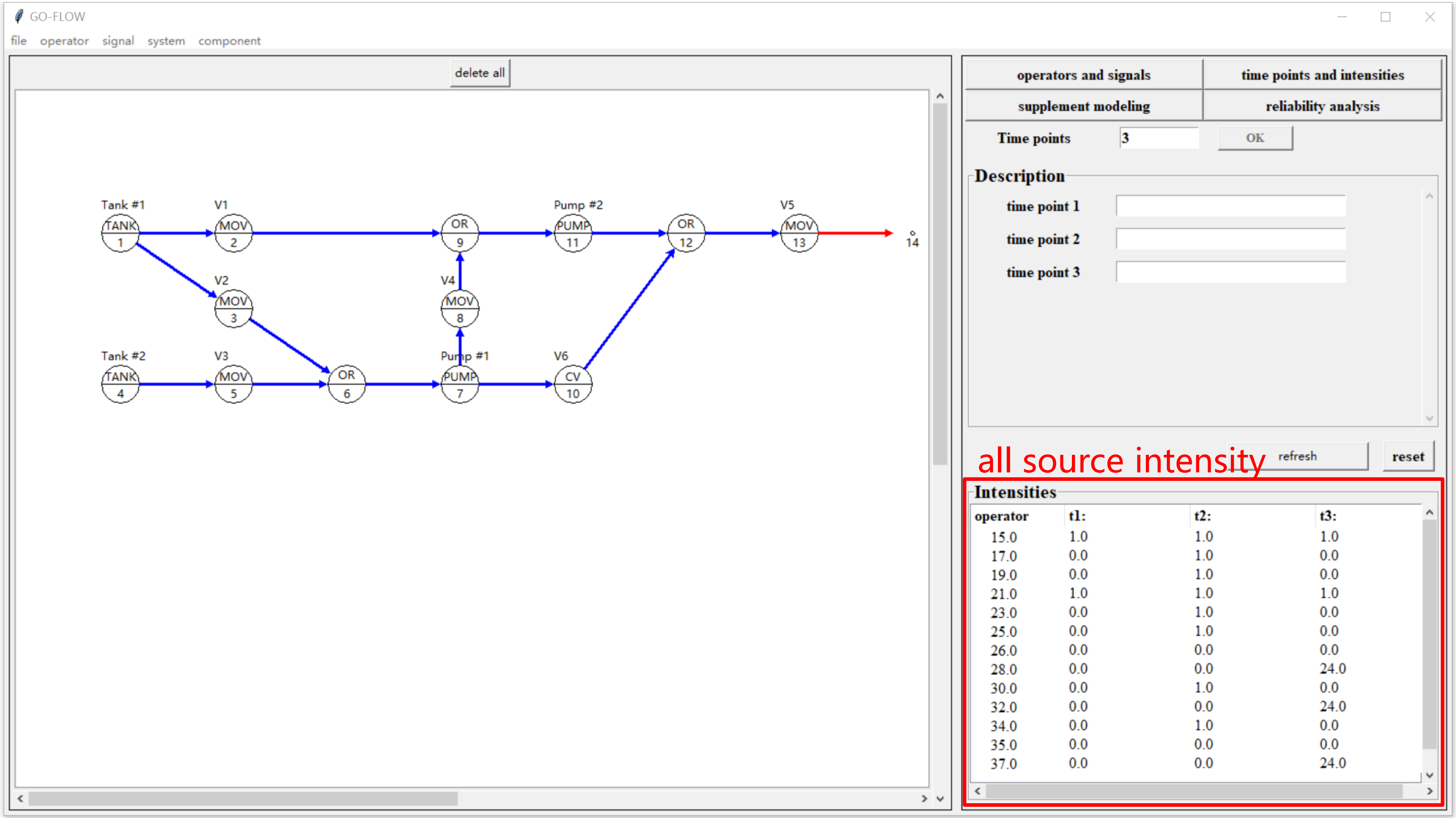
GO-FLOW model draw by exist GO-FLOW



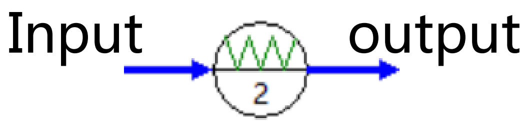
GO-FLOW model draw by new platform

- GO-FLOW platform provides a clearer model with the help of componentized operators.
- Users do not need to pay attention to the failure mode of the components.

GO-FLOW Modeling Platform for Living PSA Application



Reliability Analysis – Signal rename



	Original ideal signal	renamed signal	2^{nd} renamed signal
definition	Ratio of input signal to output signal	Conjunction of one or more original ideal signal	Processing of renamed signal by specific operators
aim	Obtain reliability of component	Improve calculation efficiency	Show signal dependency
generation	Functional GO-FLOW operators and customized GO-FLOW operator	Processing before type 22, 23, 24, 28, 30, 35, 40 GO-FLOW operator	Type 23, 24, 28, 40 GO-FLOW operator
Characteristic	Does not exist in final signal calculation	Independent between each other	dependent with renamed signal

Reliability Analysis – Signal processing

- 2nd renamed signal in one success path:

  signal merging: $S(t_i) = \min[\ S_1(t_i), S_2(t_i), \ldots\ ]$

- 2nd renamed signal in different success paths:

  signal splitting: $S(t_i) = \max[\ S_1(t_i), S_2(t_i), \ldots\ ]$

$$S_1(t_i) = \boxed{S(t_i)} * \boxed{S`(t_i)}$$

$$S_2(t_i) = \boxed{S(t_i)} * \boxed{S``(t_i)}$$

Independent signal

dependent signal

Reliability Analysis – NEA algorithm

- No repeated signal:

$$R = 1 - \prod P_i\left(S_1, S_2, \cdots\right)$$

- One repeated signal:

$$R = R_{S_i^1} \cdot S_i + R_{S_i^0} \cdot \left(1 - S_i\right)$$

$$= P\left(S_1, S_2, \cdots, S_i = 1, \cdots\right) \cdot S_i + P\left(S_1, S_2, \cdots, S_i = 0, \cdots\right) \cdot \left(1 - S_i\right)$$

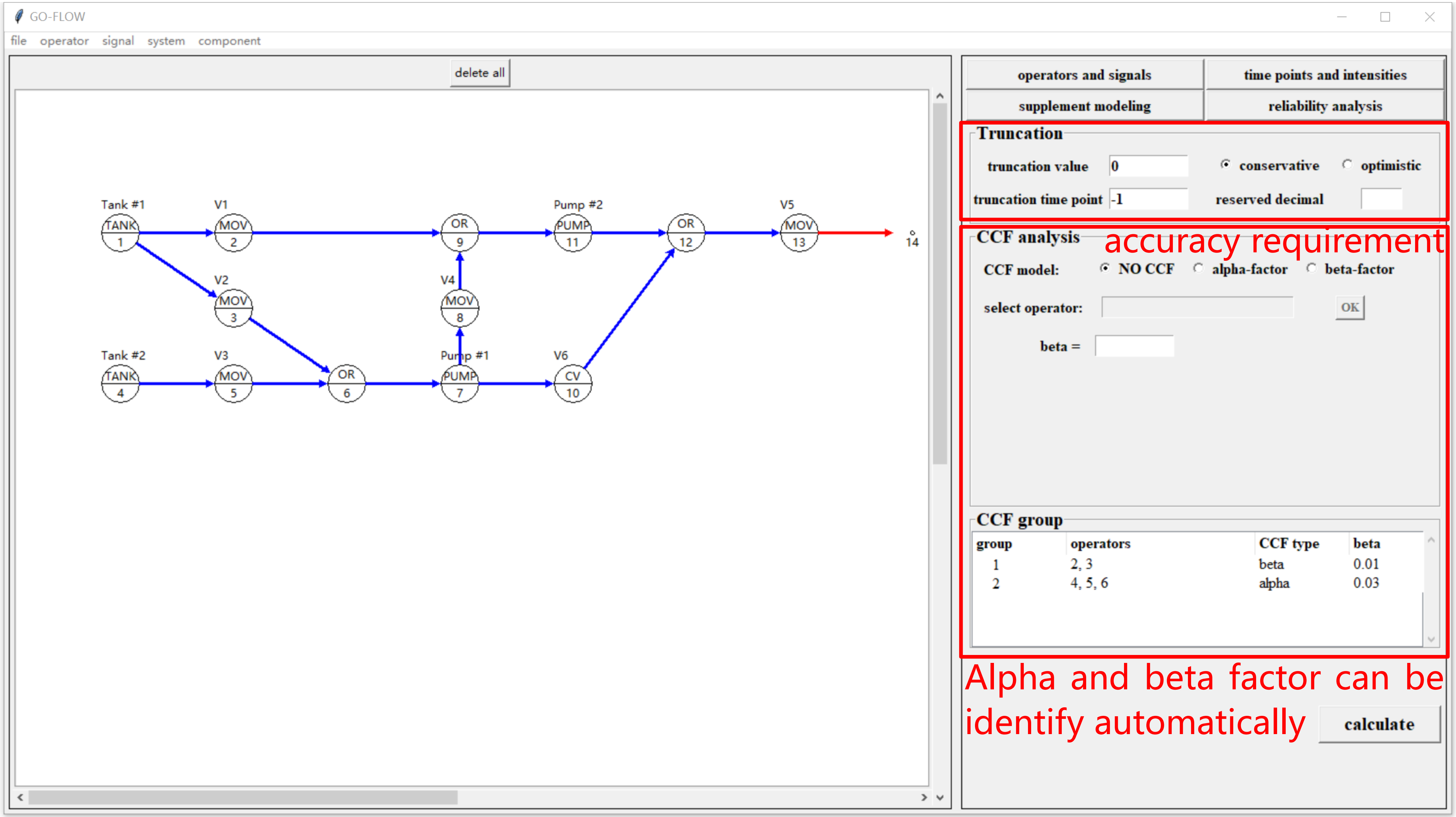
- More than one repeated signals:

$$R = R_{S_i^1} \cdot S_i + R_{S_i^0} \cdot \left(1 - S_i\right)$$

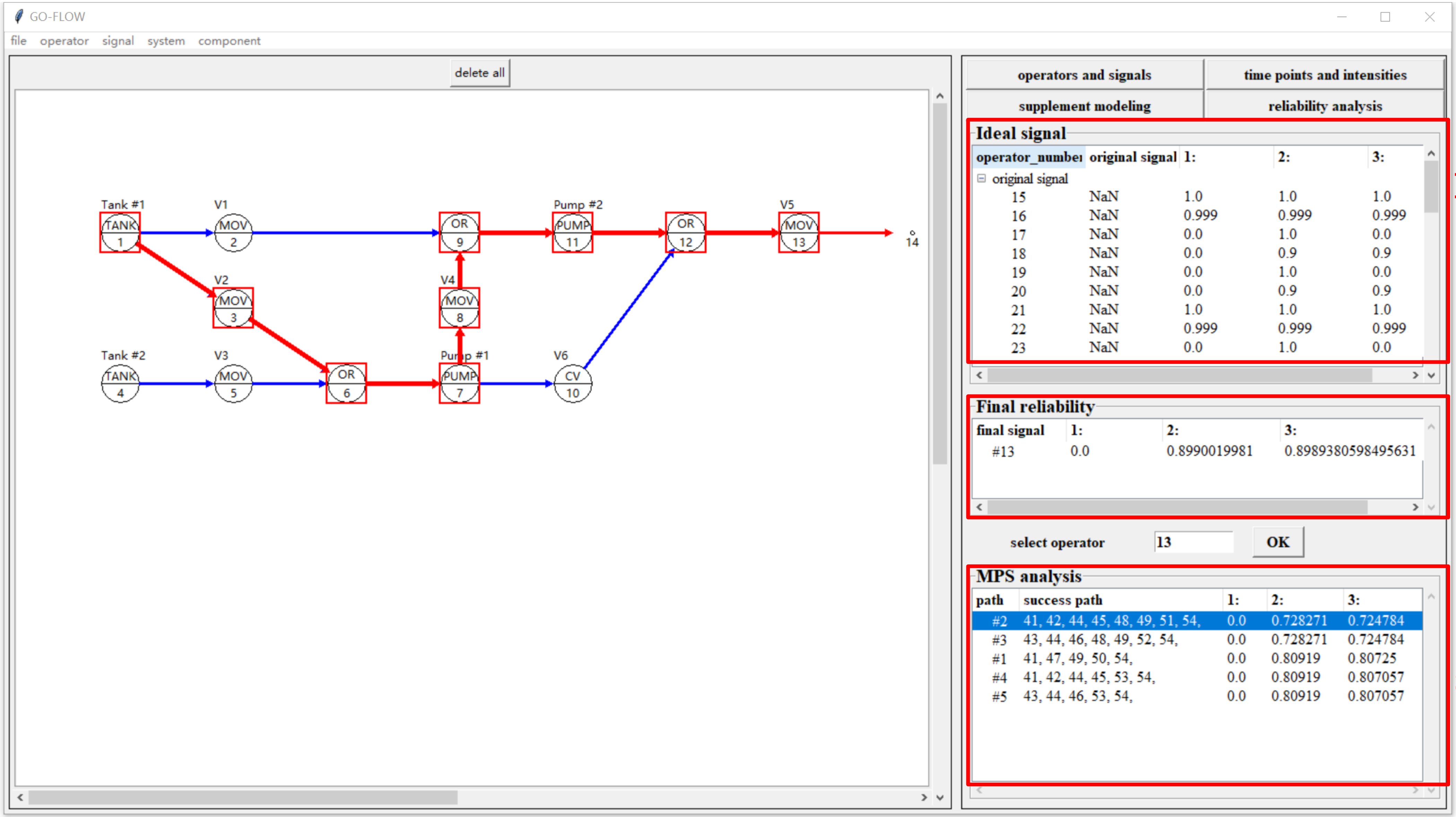
$$= R_{S_i^1 S_j^1} \cdot S_i \cdot S_j + R_{S_i^1 S_j^0} \cdot S_i \cdot \left(1 - S_j\right) + R_{S_i^0 S_j^1} \cdot \left(1 - S_i\right) \cdot S_j + R_{S_i^0 S_j^0} \cdot \left(1 - S_i\right) \cdot \left(1 - S_j\right)$$

$$= \cdots$$

Reliability Analysis – Supplement modeling



Reliability Analysis – Final result



Ideal signal

Final result

Success path set

Conclusions

- We build the table of **componentization models** which used to merge the GO-FLOW operator and map system components

- An **automated GO-FLOW modeling tool** is proposed to extract information from P&ID to GO-FLOW model data file.

- A **new GO-FLOW platform** is built with **CCF analysis** and **success path analysis** in addition to the original functions.

- **NEA algorithm** is used to improve the computational efficiency and accuracy of reliability analysis.

Thanks for listening!