

# Comparison between the GO-FLOW and the DYLAM Methodologies for the Analysis of a Dynamic System

Takeshi Matsuoka

*The GO-FLOW and the DYLAM methods are applied to an analysis of holdup tank problem with the same analysis conditions. First, the holdup tank system and analysis conditions are briefly described. The model of the GO-FLOW was explained in detail in other conference paper. The analysis results are presented and compared between GO-FLOW and DYLAM. The advantages and disadvantages of these two methods are discussed. The GO-FLOW gives accurate results with little computational time compared with the DYLAM.*

## Сравнение между методологиите GO-FLOW и DYLAM за анализ на динамични системи

Такеши Мацуока

*GO FLOW и DYLAM са приложени за анализ на задачата за поддържане на ниво в резервоар при еднакви условия на задачата. Накратко са описани системата на резервоара за поддържане на нивото и условията на анализа. Моделирането с помощта на метода GO FLOW е изложено подробно в другата статия на автора на конференцията. Показани са резултатите от анализа и са дискутирани преимуществата и недостатъците на двете методологии.*

### 1. Introduction

As engineering systems become large and complex, the dynamic aspects of man-machine-software systems become notable and it requires more advanced tools to analyse such systems. In those systems, failures, repairs, controls or operator actions influence the system dynamics; on the other hand, the system states influence component failures, controls or operator actions.

There has been a long history of developing appropriate analysis tools for dynamic systems. One of these analysis tools is the DYLAM methodology [1] and it has been used in many analyses of dynamical systems. The author has also presented the GO-FLOW methodology [2], and applied to a dynamic system [3].

In the present study, the GO-FLOW and the DYLAM are applied to an analysis of the hold-up tank problem with the same analysis conditions and the results are compared. Some discussions are given for the advantages and disadvantages of these two methodologies.

### 2. Holdup Tank Problem

A hypothetical hold-up tank problem [4] is selected as an example of dynamic system. The system consists of a tank containing water whose level is controlled by three components as shown in Figure 1. These are two inlet pumps and one outlet

valve. The pump has four possible states (on, off, failed on, failed off) and the valve has also four possible states (open, closed, failed open, failed closed).

The pumps and valve can fail at any time during operation with failure rate  $\lambda_o$ , or during standby with failure rate  $\lambda_s$ . The mission of the control system is to maintain the water level within limits by controlling the operational states of the components. The possible top events are "dry out" and "overflow".

The following assumptions are given for this hold-up tank system:

1. All the components are in normal condition at time zero.
2. Initial of the water level is in the middle of the tank depth.
3. At time zero, pump 1, pump 2 and valve, are on, off and open, respectively.
4. Failed components cannot be repaired.
5. Failures of level sensors are lumped into pump or valve failures.

Numerical conditions are given as follows.

Tank depth = 6m

Flow rates: Pump1=0.5m/h

- Pump2=0.25m/h
- Valve = 0.5m/h

Failure rates, 1/h: Pump1:

- $\lambda_{o1}$ =0.001140 (failed on)
- $\lambda_{s1}$ =0.002281 (failed off)

Pump2:

- $\lambda_{o2}$ =0.0001430 (failed on)
- $\lambda_{s2}$ =0.0002855 (failed off)

Valve:

- $\lambda_o$ =0.0015625 (failed open)
- $\lambda_s$ =0.0015625 (failed closed)

The failure rates of "Pump failed off" are set at one half of the values of "Pump failed on". Pump 2 is usually placed in standby state, so the failure rates of pump 2 are set at one tenth of the values of pump 1. From the above conditions, the following time scales have been obtained – Table 1.

Table 1. Time to overflow or dry out.

Condition	Time (hours)	Pump 1	Pump 2	Valve
Dry out	6	Off	Off	Open
Dry out	12	Off	On	Open
Overflow	12	On	On	Open
Overflow	4	On	On	Closed
Overflow	6	On	Off	Closed
Overflow	12	Off	On	Closed

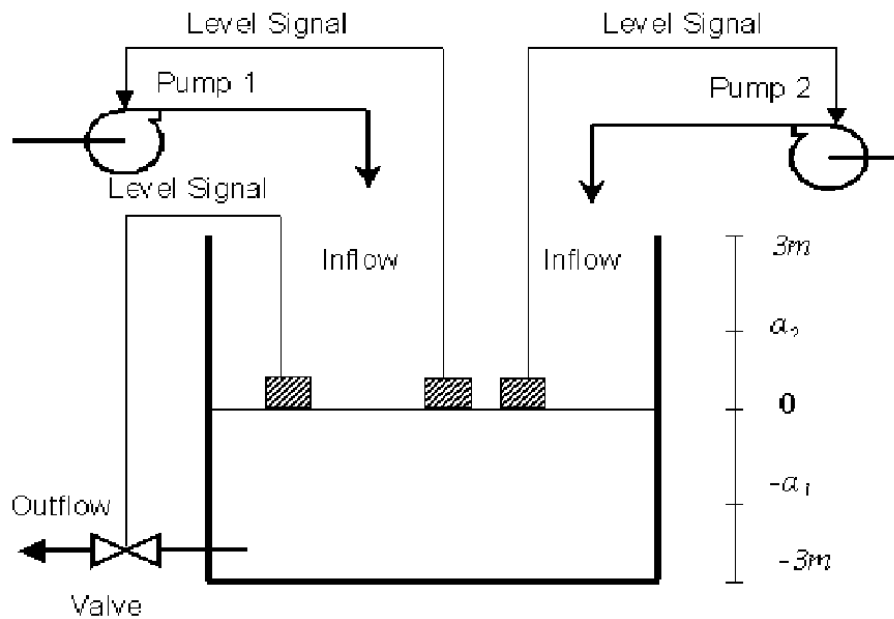


Figure 1. Hold-up tank system.

### 3. Analysis by DYLAM

The following analysis conditions are given for the analyses by the DYLAM program. Four cases are settled by the combination of different values of "cut-off threshold (PLIM) " and "time scanning interval (DTIME) ". The values of  $\alpha_1$  and  $\alpha_2$  are given as  $-0.1\text{m}$  and  $0.1\text{m}$ , respectively. By setting these values, back up or compensating action is also immediately taken in this DYLAM model. Failure rates for the pumps and valve are the same as those given in the GO-FLOW analysis. The program has been run on a Sun SPARCstation 20 (167.4MIPS).

#### Case 1:

DISK OUTPUT TIME STEP (ISTEP)	1 (hour)
CUT-OFF PROBABILITY THRESHOLD (PLIM)	1.0E-8
BRANCH POINT PROBABILITY THRESHOLD (WLIM)	1.0E+0
MISSION TIME (TMAX)	1.38E+2 (hours)
TIME SCANNING INTERVAL (DTIME)	1 (hour)
TAN.DAT = 0.0, -0.1, 0.1, -3.0, 3.0, 1, 0.00833	

#### Case 2:

DISK OUTPUT TIME STEP (ISTEP)	1 (hour)
CUT-OFF PROBABILITY THRESHOLD (PLIM)	1.0E-7
BRANCH POINT PROBABILITY THRESHOLD (WLIM)	1.0E+0
MISSION TIME (TMAX)	1.38E+2 (hours)
TIME SCANNING INTERVAL (DTIME)	1 (hour)
TAN.DAT = 0.0, -0.1, 0.1, -3.0, 3.0, 1, 0.00833	

### Case 3:

DISK OUTPUT TIME STEP (ISTEP)	1 (hour)
CUT-OFF PROBABILITY THRESHOLD (PLIM)	1.0E-6
BRANCH POINT PROBABILITY THRESHOLD (WLIM)	1.0E+0
MISSION TIME (TMAX)	1.38E+2 (hours)
TIME SCANNING INTERVAL (DTIME)	1 (hour)
TAN.DAT = 0.0, -0.1, 0.1, -3.0, 3.0, 1, 0.00833	

### Case 4:

DISK OUTPUT TIME STEP (ISTEP)	1 (hour)
CUT-OFF PROBABILITY THRESHOLD (PLIM)	1.0E-8
BRANCH POINT PROBABILITY THRESHOLD (WLIM)	1.0E+0
MISSION TIME (TMAX)	1.38E+2 (hours)
TIME SCANNING INTERVAL (DTIME)	3 (hour)
TAN.DAT = 0.0, -0.1, 0.1, -3.0, 3.0, 1, 0.00833	

### **3. Analysis results**

For GO-FLOW analysis, the results of two computer runs are joined and the range of 0 to 138 hours are covered. By the GO-FLOW analysis, occurrence probabilities for 10 possible states of the tank system have been obtained. These values are summed up to "Overflow", "Dry out" and "Within limit level" states and drawn grey lines. The required computational time was a total of 305sec - nearly 5 minutes.

The DAYLAM has given almost the same results to those of GO-FLOW. The required computational time is 2238sec (40min.), 2169sec (40min.), 729sec (12min.), 473sec (8min.) for cases 1,2,3 and 4, respectively.

The discrepancy between the GO-FLOW and DYLAM (Case 1) is seen at the beginning of "Dry out". The Case 2 shows that, using DYLAM, "Dry out" begins slightly earlier. The Case 3 gives about 8% smaller values for the occurrence probabilities of "Overflow" around 20 hours after the start of system operation. The Case 4 gives inaccurate results, especially at the beginnings of "Dry out" and "Overflow".

### **4. Discussions and conclusions**

The present analyses have not included any human behavior, but typical dynamical aspects are treated in this sample system. Failures of components produce the changes of other component's operational states and system states influence component states.

It has been shown that the results of the analyses by the GO-FLOW and DYLAM are very close to each other. They probably give accurate values in the analysis of dynamic systems. But the DYLAM requires large computational time, because it traces all the event sequences. System state  $i$  will change to state  $j$ , and

from state  $j$  to state  $k$ . In the analysis, small time interval  $\Delta t$  (DTIME) is settled, and during each time interval transitions from state  $i$  to  $j$  or from  $j$  to  $k$  occur. The DYLAM distinguishes sequences if transitions have occurred at different times. Therefore, a specific state (for example  $j$ ) consists of many different sequences. The larger the elapsed time is and the smaller the time interval is, the more the number of sequences increases. A reasonable computational time is obtained by increasing cutoff threshold and time interval, but the accuracy of results decreases as seen in "overflow" and "dry out" probabilities around 10 hours.

On the other hand, the GO-FLOW does not trace each event sequence; it performs numerical calculation as early as possible in the process of analysis. So the GO-FLOW requires little computational time. Figure 2 shows a conceptual image of the GO-FLOW analysis procedure. In this figure,  $C_n$  indicates a component, and a failure of a specific component produces a particular system state if certain surrounding conditions are satisfied. For example, a failure of  $C_1$  produces state  $i$  if some other certain components are in a failed state. During a small time interval  $\Delta t$ , a failure of component  $C_1$  or  $C_2$  or  $C_3$  increases the occurrence probability of state  $i$ . A failure of  $C_4$  decreases the occurrence probability; that is, a transition from state  $i$  to  $j$  occurs in this case. At the end of each time interval, the numerical values of the occurrence probability of system states are calculated. The GO-FLOW is not affected by when a transition from state  $i$  to  $j$  has occurred. An adequate analysis methodology is determined depending upon what kind of information should be obtained in an analysis of a dynamic system.

With a large time step, the DYLAM (3 hours in the present analysis) gives a poor result, but the GO-FLOW (6 or 50 hours time step) gives a good result if occurrence probabilities do not drastically change. There is good continuity between the results with 1 hour and 6 hours time steps. A small discrepancy is seen between the results with 6 hours and 50 hours time steps, but the result with 50 hours time step predicts satisfactorily the behavior of hold up tank system.

If one is unfamiliar with GO-FLOW methodology, it can be difficult to construct a correct chart, but actually it is not so hard a task. The DYLAM needs to express a system operational function by a group of equations, and to make a new subroutine program. In the framework of GO-FLOW methodology, an analysis support system [5] is provided, and an analyst has to handle only the GO-FLOW chart without being conscious of data structure or details of program.

In summary, the GO-FLOW gives accurate results with little computational time compared with the DYLAM. Constructing a GO-FLOW chart can easily do modeling of a dynamic system.

## 5. References

1. G.Cojazzi, P.C.Cacciabue, "The DYLAM Approach for the Reliability Analysis of Systems with Dynamic Interactions", EUR 15266EN(1993).

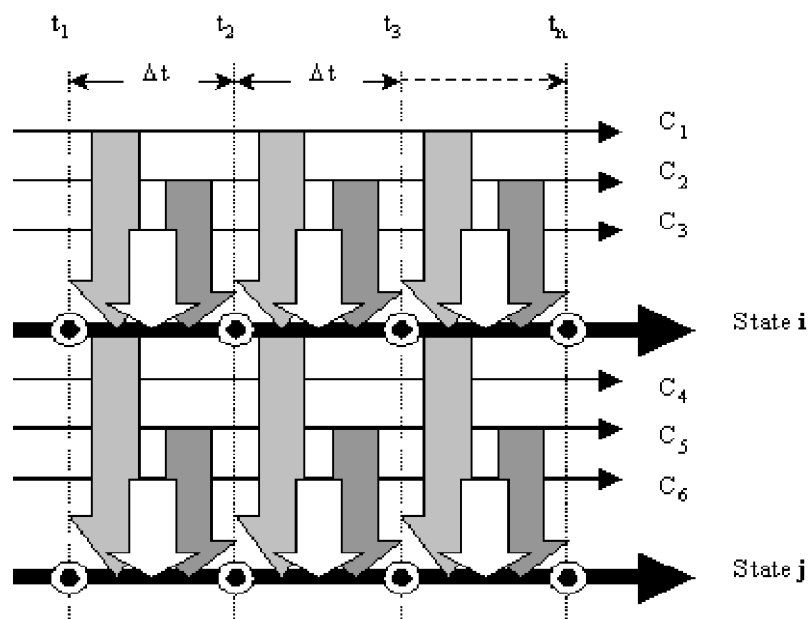


Figure 2. Conceptual image of GO FLOW analysis procedure.

2. T.Matsuoka and M.Kobayashi, "GO-FLOW A New Reliability Analysis Methodology", Nuclear Science and Engineering, Vol.98 pp.64-78 (1988),

3. T.Matsuoka and M.Kobayashi, "An Analysis of a Dynamic System by the GO-FLOW Methodology", Proceedings of International Topical Meeting, PSAM-III pp.1547-1552 (June, 1995).

4. T.Aldemir, "Computer-assisted Markov failure modeling of process control systems", IEEE Trans. Reliability, R-36, pp.133-144 (1987).

5. T.Matsuoka and M.Kobayashi, "Development of the GO-FLOW Reliability Analysis Support System", Use of Probabilistic Safety Assessment for Operational Safety PSA'91, International Atomic Energy Agency, Vienna Austria (1992) IAEA-SM-321/61 pp.677-688.

**Автор:** д-р инж. Такеши Мацуока, Национален морски изследователски институт на Япония, Директор на отдела по морска безопасност, тел. 81-422-41-3125, e-mail: [mats@nmri.go.jp](mailto:mats@nmri.go.jp)