Chapter 21

Simulation of Type PWR (Pressurised Water Reactor) Reactor Water Temperature using Optimal Discrete Control and D-Pole Assignment Method

Iksal [1,a], Saefudin[2,b]

[1] Lecturer of Department of Computer System, Faculty of Information Technology, University of Serang Raya, Banten

[2] Lecturer of Department of Information System, Faculty of Information Technology, University of Serang Raya, Banten aiksal_r@yahoo.com, bsaefudin12@gmail.com

Abstract In design of optimal control system,one of most important problems that designers dealing with is selection of Q and r weight matrix.That is how to select such the matrix so not only optimal qualification is fulfilled,but also qualification of dynamic characteristic which is consistent with specification. In solving the problem, K.Furuta and S.B.Kim from Tokyo Institute of Tecgnology,by 1987,have succeded to develop a method of selecting the weight matrix called as “D-Pole Assignment” method.It is in principle designed to put the poles of closed circle system into a circle-shaped zone with certain center and radius,which as then called as the “D-Zone”. In order to facilitate the design process, “D-Pole Assignment” method was applied in this research for design of discrete optimal control at z-plane. This research also examines computation procedur of respond matrix to Riccati P.equation,F^1 feedback vector,and Q weight matrix through the form of canonical fasevariable.Because the computation procedures of P,Q, and F^1 by “D-Pole Assignment” will difficult to be done as a result of A and b matrix which are in common form. Then the produced design procedure is applied into dynamic simulation of PLTN type PWR (Pressurised Water Reactor).The simulation performed to the control system of boiling water temperature within secondary circle of reactor,since the main effect of reactivity in reactor is caused by the temperature change.Furthermore simulation is conducted by means of investigating effect of citating period selecting on location of poles in the closed circle,and effect of change in “D-Zone” center on dynamic respond and the use control energy in closed circle system. Generally,from the simulation can be concluded that stability system became stronger when location of “D-Zone” center more and more close to unit circle center in z-plane.In order to include all poles the of the closed circle system into “D-Zone” then limits of center (α) and radius (r_2) of the the “D-Zone” would be $0,025 < \alpha < 0,40$ and $r_2 = 0,40$ respectively.

Keywords: Feedback,Weight Matrix,PWR,Phase Variable,Riccati Equation.

I. Introductions

In general, an optimal control theory is defined as a control theory that its solution seeking is based on efforts to optimize quadratic measuring rod (performance) function, and a resultant control system will be fulfilling optimal requirements as optimal input is given.

The problem is a system under design, in general, can’t to meet directly desirable specification in terms of dynamic characteristics (transient conception) of a system, since dynamic characteristics of a system is heavily depending on selected quality matrices value. K. Furuta and S.B. Kim of Tokyo Institute of Technology were successful developing a method of selecting weight matrix Q and r they called “D-Pole Assignment.” The method is designed to put closed circular system poles in a circular region having both central point and specified radius.

The method has excellences as compared with other methods, for example, Nyquist and Root-Locus and trial and error in determining weight matrix and, thus, can be applied to either continue system or discrete system. In addition, the process may be made simpler, easier, and faster as compared with other methods in high-order systems. In this method, we are able to get directly weight matrix Q and r and feedback F^1 that guarantee the compliance of optimal criteria and desirable specification of a system.

II. Objective

The aim of this study is to prepare optimal feedback F^1 accounting procedure and weight matrix Q and r in discrete time area. Furthermore, the planning procedural output is tried out in the simulation of PLTN Type PWR dynamics, particularly the systematization of boiled water temperature in a secondary reactor circle.

III. Problem Solving Method

Because of difficulties in weight matrix Q and optimal feedback F^1 vector counting processes by "D-Pole Assignment" as matrices A and b have even common shapes, the following steps to solve the problems are taken:

a. Numerous input systems are transformed into single input system of common type.
b. Single input system of common type is transformed into single input system of variable phase canonic type.
c. For the accounting output in step (b), optimal feedback [illegible]$_1$ ~ vector accounting procedure, Riccati equation matrix [illegible]$_1$ ~, and weight matrix $\tilde{Q}$ are reduced to quadratic display measuring rod.
d. Accounting output in step (c) is transformed again into single input system of common type.
e. Accounting output in step (d) is transformed again into input system of multiple common types.

IV. Basic Theory

a. D-Pole Assignment Method

"D-Pole Assignment" method in discrete system is, essentially, designed to put whole closed circular system pole in a specified circular region having central point and radius on α area, placed in a circular region with single radius on z area as shown in Fig. 1, location of D region on z area, as follows.

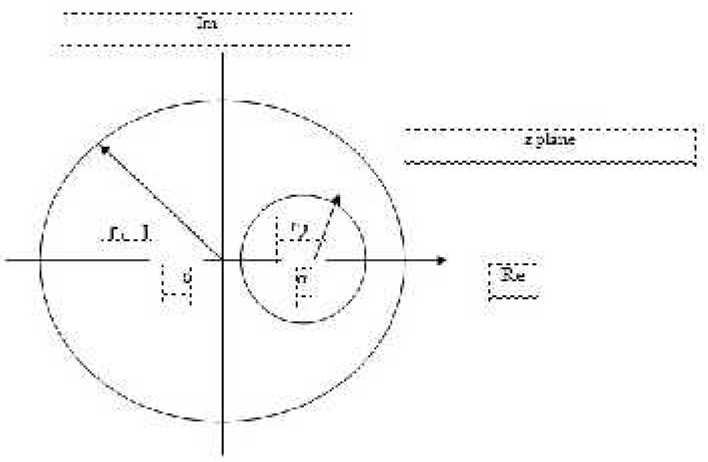

Fig. 1:Location of D-Region z plane

For the quality matrices fulfilling optimal requirements and "D-Pole Assignment", the reductions of equation are as follows.

$$Q=P_1+ \tfrac{2}{2}\, Q_1-\alpha\, P_1\, A-\alpha\, A^T\, P_1 + (\alpha^2 - r^2)\, P_1 \qquad (1)$$

$$r= \tfrac{2}{2}\, r_1 \qquad (2)$$

b. Nuclear Power Electric Plant of PWR Type

Fig. 2, primary and secondary circle of PLTN type PWR all represent PWR reactor system. Reactor here is source of heat energy. The heat is extracted by passing through coolant to the reactor. The heat energy, subsequently, is transferred to turbine through "steam generator".

For PWR generator, the equations to be reduced are kinetics, transfer of heat from fuel to water, equilibrium of heat for the cooling water in then kernel of reactor, transportation deceleration, and temperature escaping from the steam generator,

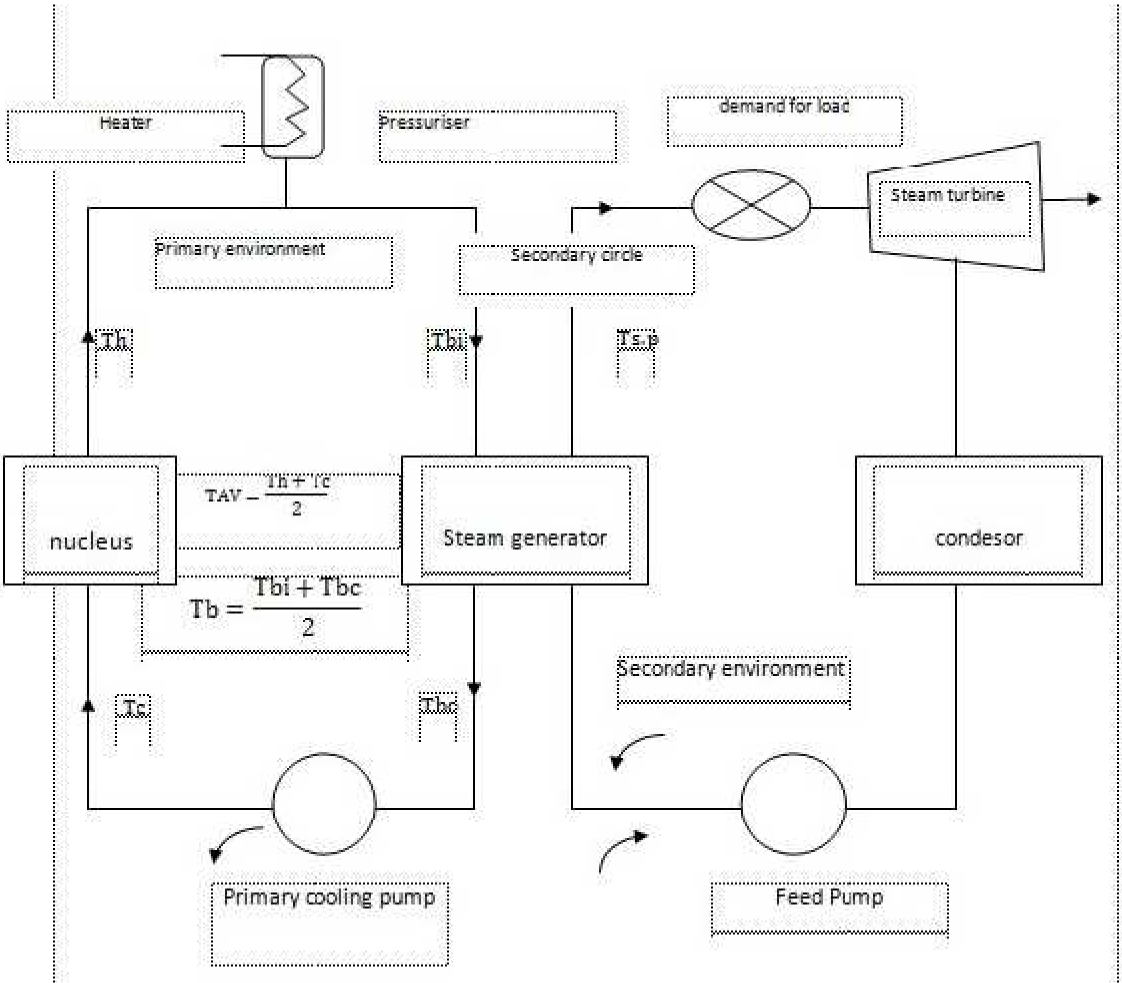

Fig. 2:Primary and Secondary Circle of PLTN Type PWR

V. Results and Discussion

a. Fig. 3 is simulation of boiled water temperature deviation in secondary circle of reactor over the selection of “D Region” (variation of α) on unit ladder input.

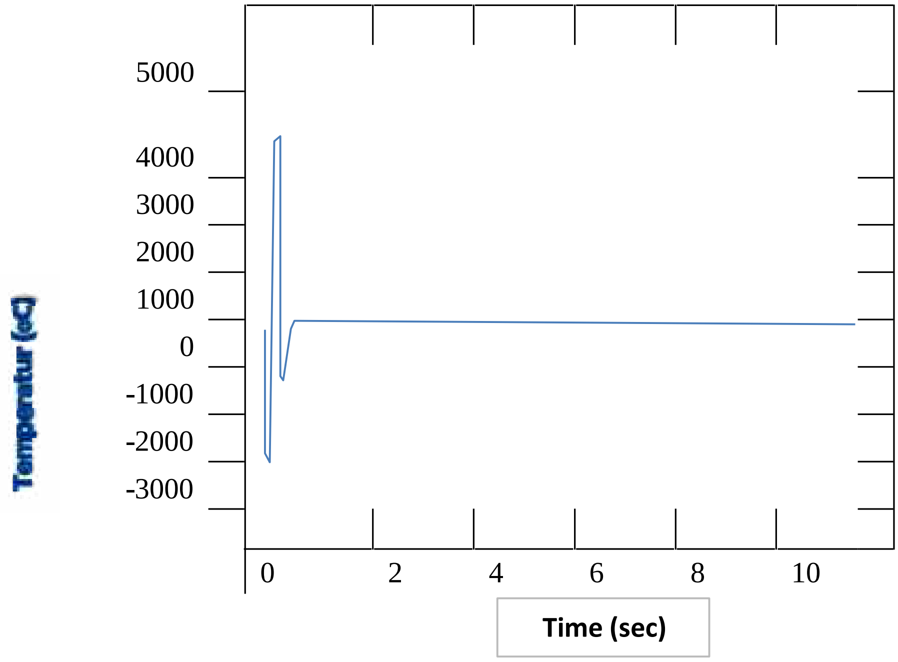

Fig. 3: Simulation of Boiled Water Temperature

The results of the simulation shown that: 1) the more near the central point of “D Regional” (α) to the center of unit circle, better the stability of system will be, 2) maximum overshoot is bigger when α is smaller, 3) when α is smaller, the controlling signal will be bigger.

b. Fig. 4 is simulation of boiled water temperature deviation in secondary circle of reactor over the variation of time sampling value.

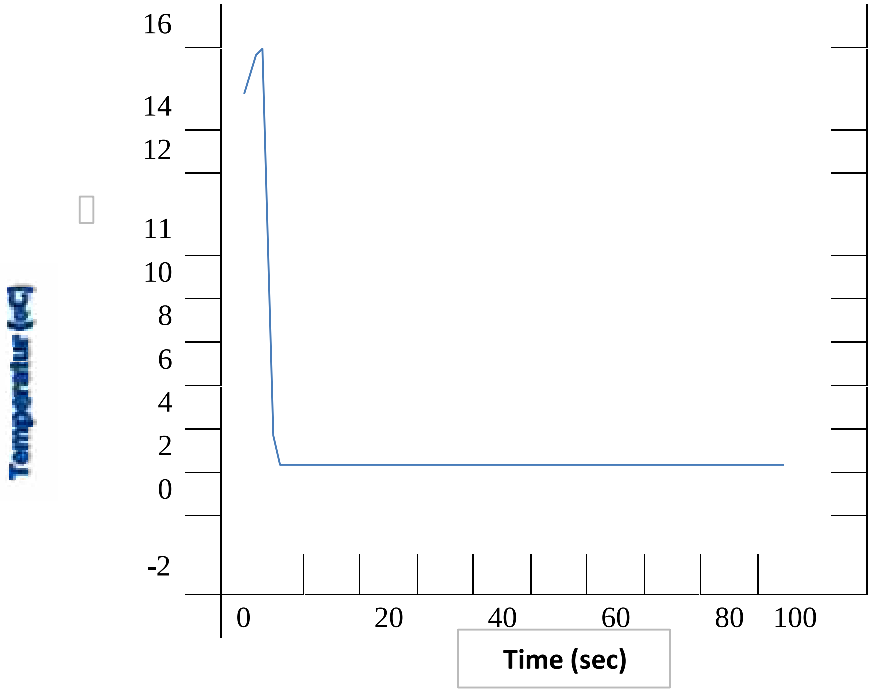

Fig. 4: Simulation of Boiled Water Temperature

The results of the simulation shown that T_s is enlarged by constant α and r_2, it is seemed the reaction of system is lower (the stability of system is longer).

VI. Conclusions

Based on the results of the simulation, the conclusions might be drawn as follows:

1. Weight matrix Q and r and feedback F^1 vector might be found by "D-Pole Assignment" method.
2. When α is smaller: the system is more quickly stable, maximum overshoot is bigger, and controlling signal is larger.
3. When T_s is larger, the system is slower to reach the stable point.
4. The selection of best "D Region" is $0.025 \leq \alpha \leq 0.40$ and $r_2 = 0.40$; it is due to the desirable specification of system is met in the region.

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