

# Modeling of turbine follow control with internal model control tuning method based on hysys

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**Abstract.** The power plant is one of the several industries whose product are used by consumers directly. The power plant requires an appropriate control strategy based on real-plant to maintain electricity production,. Turbine Follow Control (TFC) is one of the several control strategies for keeping electricity production. TFC is a control strategy that used to control throttle pressure based on Advanced Regulatory Control (ARC) concept. When there is a change of load on the generator, the error signal will be received by the indicator control. The error signal is used to respond fuel arrangement to maintain the main steam production. Furthermore, the changes of main steam production indicated by the pressure indicator control. It will be responded by the turbine governor valve to carry out a follow-up response in maintaining the main steam towards the turbine. The actual response is given in the form of the percentage of valve. This paper has been modeled TFC strategy using Internal Model Control (IMC) tuning method and First Order Plus Dead Time (FOPDT) approach for getting good control response based on HYSYS. In addition, IMC tuning response in this paper also depends on the  $\pm 5\%$  from setpoint test. From modeling of TFC based on HYSYS, the simulation shows that TFC is precise control strategy to handle the changes of load on the generator with integral absolute error value are 102,087.7 for +5% from setpoint test and 122,947.1 for -5% from setpoint test.

## 1. Introduction

Power plant products are used by consumers directly in every life sectors. In the process of maintaining electrical products, there are various efforts that can be done, such as performance evaluation of each unit operation, maintenance management, control strategy, and using high efficiency of unit operations. From these efforts for maintaining power production, the control strategy is the most precise effort considering simplification method for applying on the plant and cost of the operational process. At the power plant, there are several control strategies that are often used, namely boiler follow control (BFC), turbine follow control (TFC) and coordinated control (CC) [1]. These control strategy is used to maintain system reliability, mass, and energy balance, and set point value of several unit operations. Jacques Smuts, describes the concept of Advanced Regulatory Control (ARC) strategy as a way to control the operating units of boiler and turbine. ARC strategy classification is grouped by application. Turbine follows control (TFC) is part of controlling's application pressure valve (throttle pressure) [1]. Black and Veatch, explains the principle of turbine follow control strategy and provides the advantage and disadvantage of using TFC in power plant. TFC is used when load changes occur in the generator, the resulting error signal will be received by the controller indicator to respond to the fuel arrangements in order to maintain the main steam production. Furthermore, the



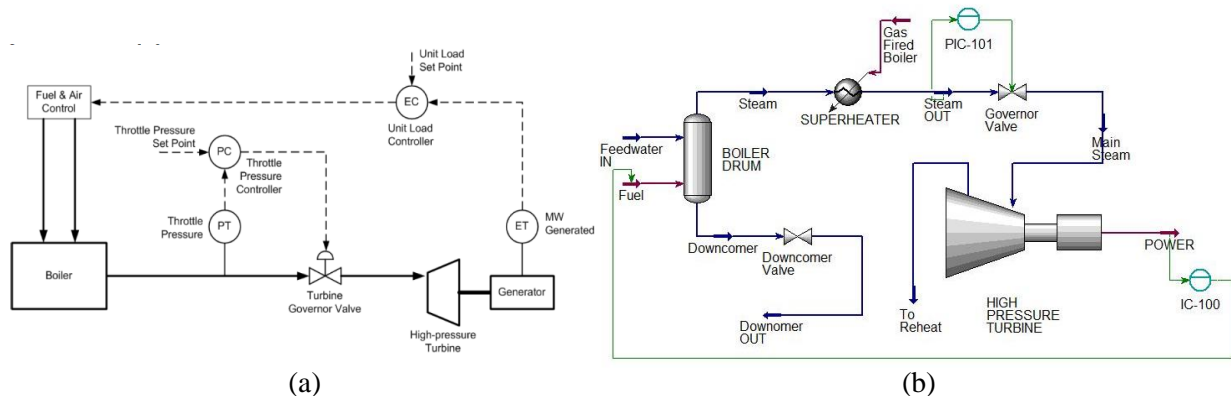
main steam production changes indicated by the pressure parameters will be responded by the turbine governor valve for further response in maintaining the main steam toward turbine. The actual response is given in the form of the percentage of a valve. Based on the control process, the structure of TFC scheme has a feedback control [2].

PI/PID control is assessed to produce a rapid system response [3]. Simple and easily understood algorithms are also the reasons that PI/PID control is often used [4]. Basically, PI/PID control needs to pay attention to the tuning process, i.e. the process of determining the characters  $K_c$ ,  $\tau_i$ , and  $\tau_d$  in order to obtain the desired system response [5]. However, PI/PID control only is not sufficient to be applied to a power plant. Actually, PI/PID control is only used for linear conditions. Whereas given the complex system of the power plant, the resulting response tends to be nonlinear [6]. Therefore, in applying the design model of power plant control system, a true plant-based control strategy [7], which can be done by PID-based Internal Model Control (IMC) tuning method. To obtain PID tuning parameters, a mathematical approach is required based on real plant. Zhang Yao and Huang Chunqing simulate an IMC-PID control process through First Order Plus Dead Time (FOPDT) approach by considering filter ( $\lambda$ ) [8]. The use of filters ( $\lambda$ ) is considered capable of minimizing the integral absolute error (IAE) value for step response. In the simulation performed, filter ( $\lambda$ ) has criteria referring to previous research. Rivera et al. [9] gives a value of  $\lambda > 0.8\Theta$ ;  $\lambda > 0.1\tau$ . Chien and Freuhauf [10] gives  $\Theta < \lambda < \tau$  values. While Sigurd Skogestad [11] gives a value of  $\lambda = 1$ .

This study will find a precise tuning method for turbine follow control (TFC) with real condition with the help of simulation program in the form of hysys.

## 2. Modeling and Operating Conditions

The structure of TFC strategy is based on the feedback control mechanism with the output parameters in the form of a percentage of control valve openings. The control input on the TFC strategy consists of changes in load and changes in main-steam pressure. TFC structure is shown in figure 1(a).



**Figure 1.** (a) Turbine follow control structure (b) Process modeling with hysys in dynamic mode

In this paper, the modeling process is done by using HYSYS software. To obtain a modeling process that is appropriate to the actual plant conditions, P&ID and operational data scheme are required. The use of the P&ID scheme aims to represent the concept of the TFC strategy. P&ID modeling in HYSYS software is shown in figure 1(b). Whereas, the operational data required fulfilling the process simulation parameters in HYSYS, at least include mass flow, pressure or temperature that can be shown in table 1.

**Table 1.** Operating condition of power plant

Variable	Parameters	Unit	Value
<i>Feedwater Outlet</i>	Temperature	°C	352.82
	Pressure	bar	182.93
	Mass flow	kg/h	927,389.35
<i>Main Steam</i>	Temperature	°C	535.46
	Pressure	bar	162.62
	Mass flow	kg/h	976,027.92
<i>Reheat Steam</i>	Temperature	°C	346.07
	Pressure	bar	35.50
<i>HP Turbine</i>	Efficiency	%	82.57

### 3. Methodology

#### 3.1. Open-Loop

The open-loop control system is a system whose output has no effect on the control action. In reality, on an open-loop control system is applied by manually opening the valve engine process. In the simulation process, the open-loop control system is used as a test condition. The open-loop test is used to find the transfer function of a process by First Order Plus Dead Time approach.

FOPDT is a mathematical model for obtaining a transfer function of a process which is then used to determine the PID tuning parameters of  $K_c$ ,  $\tau_i$  and  $\tau_d$  [12] based on the basis of the tuning method used. The FOPDT mathematical model is an approach model that is widely used by industry as a method of controlling tuning approach.

To obtain the transfer function, it is approximated by the PRC equation of Cecil L. Smith [13] shown in the following equation (1), (2), and (3).

$$K = \frac{\Delta}{\delta} \quad (1)$$

$$\tau = 1,5 (t_{63\%} - t_{28\%}) \quad (2)$$

$$\theta = t_{63\%} - \tau \quad (3)$$

where

- $K$  = Gain of steady-state
- $\Delta$  = The magnitude of changes in the external variable
- $\delta$  = The amount of change in input variables that affect the output variable
- $t_{63\%}$  = Output response time reaches 63%
- $t_{28\%}$  = Output response time reaches 28%
- $\tau$  = Time constant
- $\theta$  = Dead time

#### 3.2. Internal Model Control

The Internal model control PID (IMC-PID) is one of the controlling tuning methods that can only be achieved if the system contains parameters of the process to be controlled, either implicitly or explicitly [14]. IMC-PID can also be said as a method designed to control feedback from the output of a process.

The structure of the IMC-PID control method uses the transfer function of the process to locate the transfer function of the controller. Indirectly, the IMC-PID method is also an advanced process of determining the parameters  $K_c$ ,  $\tau_i$ , and  $\tau_d$ .

Sigurd Skogestad formulates the stages of IMC-PID tuning as follows:

1. Modeling the system will produce the result characteristics of the consecutive equation
2. Create an open-loop system response by changing the controller mode: auto becomes manual. And change the set point value by  $\pm 10\%$  of the specified value
3. Using test signal in step signal. Because the step signal will produce an easy to observe system response
4. Using FOPDT method from open-loop response result to get parameters of values  $\theta$ ,  $\tau$ ,  $K$ ,  $t_{63\%}$ , and  $t_{28\%}$
5. Specifies the control parameters of the values of  $K_c$ ,  $\tau_i$ , and  $\tau_d$  with the value of the transfer function based on the IMC-PID Controller Tuning Rules table [13]. For the value of  $K_c$ ,  $\tau_i$ , and  $\tau_d$  is given in equation (4), (5), and (6) below.

$$K_c = \frac{\tau_I}{K(3\lambda - 2\beta + \theta)} \quad (4)$$

$$\tau_I = (\tau + 2\beta) \frac{\left(3\lambda^2 - \frac{\theta^2}{2} + 2\beta\theta - \beta^2\right)}{(3\lambda - 2\beta + \theta)} \quad (5)$$

$$\tau_{Dc} = \frac{(2\tau\beta + \beta^2) - \frac{\left(\lambda^3 + \frac{\theta^3}{6} - \beta\theta^2 + \beta^2\theta\right)}{(3\lambda - 2\beta + \theta)}}{\tau_I} - \frac{\left(3\lambda^2 - \frac{\theta^2}{2} + 2\beta\theta - \beta^2\right)}{(3\lambda - 2\beta + \theta)} \quad (6)$$

6. Performed analysis of control performance results.

### 3.3. Closed-Loop

The closed-loop control system is a system that measures the actual output of a process and compares it with the output set point. In a closed-loop system, the comparison of output condition with the desired condition (set point) can be analysed in qualitative and quantitative through the graph of system performance analysis as shown in three parameters below.

1. *Settling Time*  
Settling time is the time required by the response curve to exactly reach an absolute percentage value of 2% or 5% of the reference value (set point)
2. *Maximum Overshoot*  
Maximum overshoot (MO) is the maximum peak value of the response curve as measured from the beginning of the change. To determine the MO value can be expressed as a percentage through the following equation (7) approach.

$$MO = \frac{c(t_p) - c(\infty)}{c(\infty)} \quad (7)$$

3. *Integral Absolute Error (IAE)*  
Integral absolute error (IAE) is the sum of the error values of the resulting output response. The IAE criteria are preferred among ease industry practitioners in the measurement process. To calculate IAE value can be done by using the following equation (8).

$$IAE = \int_0^\infty |SP(t) - CV(t)| dt \quad (8)$$

## 4. Result and Discussion

At this stage, results and analysis of the TFC modeling process with IMC-PID tuning method will be presented.

### 4.1. Open-Loop Test Based on Control Valve Change

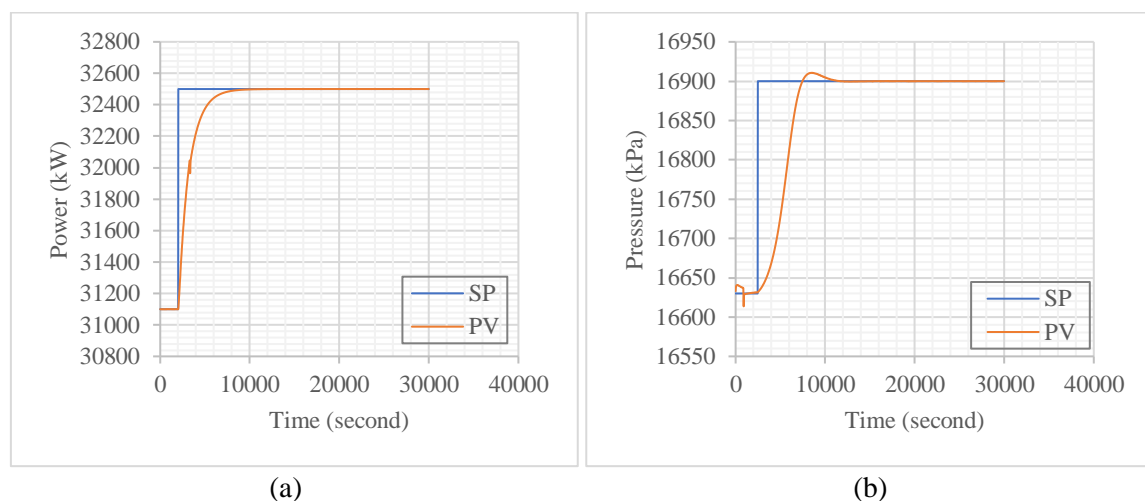
Open-loop simulation aims to find the transfer function process. The data is taken with operational valve change of 10% in 30 minutes duration on each laying of the controller. Based on the P&ID of the TFC strategy in figure 1., the controllers involved are the pressure indicator control (PIC) and the power indicator control (IC). The necessary data include an operation (OP), process variable (PV) and time in seconds. Furthermore, with FOPDT approach through PRC Cecil L. Smith equation (1), (2), (3) and considering open-loop graphic result, the value of parameters such as  $\Theta$ ,  $\tau$  and  $K$ , for PIC and IC shown in table 2.

**Table 2.** FOPDT parameters on PIC and IC

Instrument	Parameter	Unit	Value	Instrument	Parameter	Unit	Value
IC	$\Theta$	second	0	IC	$\Theta$	second	0
	$\tau$	second	45.6024		$\tau$	second	39.7177
	$K$	-	16.551		$K$	-	1.590

### 4.2. Closed-Loop Test Based on Set Point Change

The analysis of closed-loop test refers to the use of known parameters such as  $K_c$ ,  $\tau_i$ , and  $\tau_d$  to perform control actions based on  $\pm 5\%$  setpoint change. Analysis of IC and PIC control responses based on  $+5\%$  set point change are respectively shown in Figures 2.



**Figure 2.** (a) IC closed-loop test (b) PIC closed-loop test

Based on figure 2 (a) and (b), it can be seen the quality of the control response. Through  $\pm 5\%$  setpoint test, IC and PIC can meet the requested setpoint well. This is shown on the line of PV charts coinciding with the set point after the change. The process illustrates that the TFC strategy can meet set point changes. The control process also showed that the control scheme can't occur quickly. The control process in achieving the setpoint value had a certain time span. In quantitative response analysis, the performance of TFC control with IMC-PID tuning can be assessed by calculating settling time, maximum overshoot (MO) and integral absolute error (IAE). These three parameters of quantitative response analysis are shown in table 3.

**Table 3.** Closed-loop test based on set point change  $\pm 5\%$ 

Respond Analysis	IC		PIC	
	+5%	-5%	+5%	-5%
Settling Time	11,680	11,000	12,780	26,680
MO (%)	14.0	0.00	0.30	0.00
IAE	86,208.0	85,586.5	39,879.7	37,360.6

Based on the quantitative response analysis, the table showed every control strategy had a certain time span to achieve each set point. In each control instrument also showed that TFC can work quickly and accurately according to set point based on small of MO value.

## 5. Conclusions

The emphasis of this study is to the quantitative response of tuning TFC in the power plant as the variation of set point change  $\pm 5\%$ . For the results of modeling process above, the conclusions are summarized that TFC is precise control strategy to handle the changes of load on the generator.

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