Development of Educational Tool in Modeling Short Term Hydrothermal Scheduling

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Abstract — In this paper, a Graphical User Interface (GUI) has been developed in modeling and solving short term hydrothermal scheduling on power system. This graphical user interface (GUI) can be an educational tool that helps in improving the interest and understanding of the users on short term hydrothermal scheduling problem in more interactive and interesting way.

Index Terms – Short term hydrothermal scheduling, educational tools, classical method, Graphical User Interface (GUI)

I. INTRODUCTION

The usage of educational tools in helping the users to understand problems related to power engineering has become essential. By simulating the problems in software like MATLAB®, the users can get a better picture on specific problems and the ways to solve it. These simulations can serve as self-paced learning modules, where the users can try using it themselves and understand how every system works. In this paper, the problem that been discussed is regarding short term hydrothermal scheduling. In this paper, short term hydrothermal scheduling problem is represented in Graphical User Interface (GUI).

Basically, short term hydrothermal scheduling is essential in order to optimize the operational cost for generating electricity. Short term operation planning usually covers a time range between one day to a week. The primary objective of short-term hydrothermal scheduling is to determine the amount of hydro and thermal generations to meet the load demands in a schedule horizon so that the fuel cost required to run the thermal generators can be minimized. In dealing this problem, the thermal system may be represented by an equivalent thermal generator unit. As the scheduling interval of short range problem is small, the solution of the short-range problem can assume the head to be fairly constant. Different methodologies for solving short term hydrothermal problem have been proposed such as hybrid solution[1], cultural algorithm[2] and genetic algorithm[3].

II. LITERATURE REVIEW

Some technical papers proposed the implementation of educational tools as an example in enhancing the understanding of power engineering.

For example, in [4] a mathematical software named "GPMS" that can handles general and specific mathematical formulas and is packed with a vast array of codes has been used to perform many scientific and engineering functions in an interactive mode. Other technical paper like [5] stressed about the application of Spice simulations software on power electronics circuits that been used for power quality improvement and to simulate the undesirable effects on a power system.

Many electrical and power systems engineering laboratories must be in virtual form due to the risky condition and some of the equipments required are often expensive. For example, the practical cannot be done in HV transmission system as it is too dangerous and risky. In [6],NEPLAN software has been used for the assessment of laboratory activities for the Power Systems course.

Meanwhile, Badrul H. Chowdhury and Dennis E. Clark in [7] introduced a tool calls COPERITE that has user interfaces completed with menus and attractive graphical representations. This tool can be used to demonstrate power flow, contingency analysis, economic dispatch, system stability and fault analysis.

List Of Symbols

$\alpha_{hi},\beta_{hi},c_{hi}$	Coefficient for hydro plant
λ_j	Incremental cost
F_i	Cost function for thermal plant
$\alpha_{thi},\beta_{thi},c_{thi}$	Coefficient for thermal plant
C_{th}	Loss coefficient for thermal
γ_{th}	gamma for thermal plant
P_{Loadj}	Load power during j time
P_{lossj}	Transmission loss
P_{thk}	Thermal power at k iteration
W_{total}	Total volume of water
P_{lossk}	Transmission loss at k^{th} iteration
P_{loadk}	Load demand during k^{th} iteration

III. METHODOLOGY

A. Classical Method

A general and basic short-term hydrothermal scheduling problem requires that a given amount of water be used in such a way to minimize the cost of running the thermal units. In this paper, the classical method has been used to solve the short term hydrothermal scheduling. In Figure 1 below, the thermal system is represented by an equivalent unit, P_{thj}. In this case, there is a single hydroelectric plant, P_{hj}. The hydro plant is supplying power to the load at maximum. It is assumed that the hydro plant is not sufficient to supply all the load demands during the period and that there is a maximum total volume of water that may be discharged throughout the period of T_{max} hours. In setting up this problem and the examples that follow, all spillages, S_j are assumed to be zero. The only other hydraulic constraint being impose initially is that the total volume of water discharged must be exactly as defined.

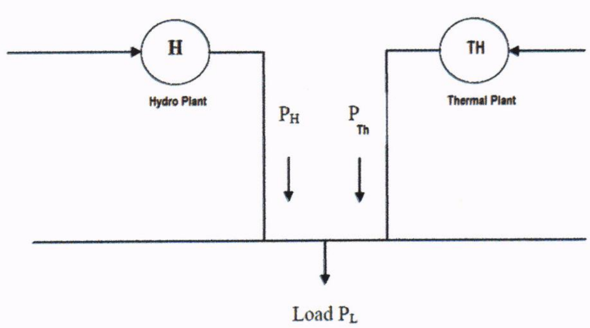

Figure 1 : Relationship between thermal plant and hydro plant

(Load energy) - (Hydro energy) = (Thermal energy)

For any time period j,

$$\sum_{j=1}^{jmax} P_{hj}^{max} \geq P_{loadj} \quad j = 1\ldots\ldots.j_{max} \tag{1}$$

However, the energy that can be supplied by the hydro plant is insufficient compare to the load requirement

$$\sum_{j=1}^{jmax} P_{loadj}\times n_j \leq \sum_{j=1}^{jmax} P_{loadj}\times n_j \tag{2}$$

n_j = numbers of hours in period j

$$\sum_{j=1}^{jmax} n_j = T_{max} = \text{total interval} \tag{3}$$

In order to minimize the cost of running the thermal plant, the thermal energy required is

$$\sum_{j=1}^{jmax} P_{loadj}\times n_j - \sum_{k=0}^{n} P_{hj}\times n_j = \sum_{j=1}^{Ns} P_{thj}\times n_j \tag{4}$$

Thermal Plant

For thermal plant, the cost function is given by :

$$C = \sum_{k=1}^{T}\sum_{i=1}^{N} t_k F_i(P_{ij}) \tag{5}$$

$$F_i = \alpha_{thi}P_{thi}^2 + \beta_{thi}P_{thi} + c_{thi} \quad k = 1\ldots..T, i = 1\ldots\ldots.N, \tag{6}$$

Hydro Plant

$$W_{ik} = \alpha_{hi}P_{hi}^2 + \beta_{hi}P_{ik} + c_{hi} \quad i = 1\ldots\ldots.N \tag{7}$$

Load demand equality constraint

$$\sum_{i=1}^{N} P_{ik} = P_{loadk} + P_{lossk} \tag{8}$$

Transmission loss during k^{th} interval is given

$$P_{lossk} = \sum_{i=0}^{N}\sum_{i=0}^{n} P_{ik}B_{ij}P_{ik} + B_{i0}P_{ik} + B_{00} \tag{9}$$

$$\text{Min Ft} = \sum_{k=0}^{n} n_j F_j \tag{10}$$

$$\sum_{j=1}^{jmax} n_k W_k = W_{total} = \text{total water discharge} \tag{11}$$

$$P_{loadj} - P_{hj} - P_{thj} = 0, \quad j = 1\ldots.j_{max}$$

Let n_j = length of j^{th} interval

$$\sum_{j=1}^{jmax} n_j = T_{max} \tag{12}$$

Assume constant head operation and assume a W versus P characteristic is available, so that

$$W_{total} = W\times P_H \tag{13}$$

Lagrange function without considering the transmission loss

$$\pounds = \sum_{j=1}^{Ns} F(P_{ht})n_j + \lambda_j (P_{loadj} - P_{hj} - P_{thj} = 0) + \gamma (n_j W_j (P_{hj}) - W_{total} \quad (14)$$

for a specific interval j = k,

$$\frac{\partial \pounds}{\partial Pth} = 0$$

$$n_j \frac{dy}{dx} = \lambda_k \quad (15)$$

and

$$\frac{\partial \pounds}{\partial Phk} = 0$$

Gives

$$\gamma n_k \frac{dy}{dx} = \lambda_k \quad (16)$$

Consider the network loss

$$P_{loadj} + P_{lossj} - P_{hj} - P_{thj} = 0 \quad (17)$$

Finally, the Lagrangian function with transmission loss becomes

$$\pounds = \sum_{j=1}^{Ns} F(P_{ht})n_j + \lambda_j (P_{loadj} + P_{lossj} - P_{hj} - P_{thj} + \gamma (n_j W_j (Ph_j) - W_{total}) = 0 \quad (18)$$

Final coordination equation for hour (j) :

$$n_j \frac{dFi}{dPthj} + \lambda_j \frac{\partial Plossj}{\partial Pthj} = \lambda_j \quad (19)$$

$$\gamma_j n_j \frac{dW(Phj)}{dPhj} + \lambda_j \frac{\partial Plossj}{\partial Phj} = \lambda_j \quad (20)$$

Figure 2 below shows the flow chart in solving short term hydrothermal scheduling. On the first stage, the users insert the values of coefficients for both thermal and hydro plant together with other variables. All this variables will then be inserted into coordination equation to determine power loss, thermal power and hydro power. On the next step, the total power produced is compared with coefficient, $\varepsilon 1 = 0.1$,and if the condition is satisfied, total water required in generating power for hydro plant will be calculated. The required water volume needed by the hydro plant is compared with the available water at the hydro plant. If the value of comparison does not lower than $\varepsilon_2 = 50$, the process will return to coordination equation in order to determine the new value of γ. Finally, the final value for P_{th}, P_h, Volume of water required, V_{nett} , λ_{final} and γ_{final} will be displayed for the users.

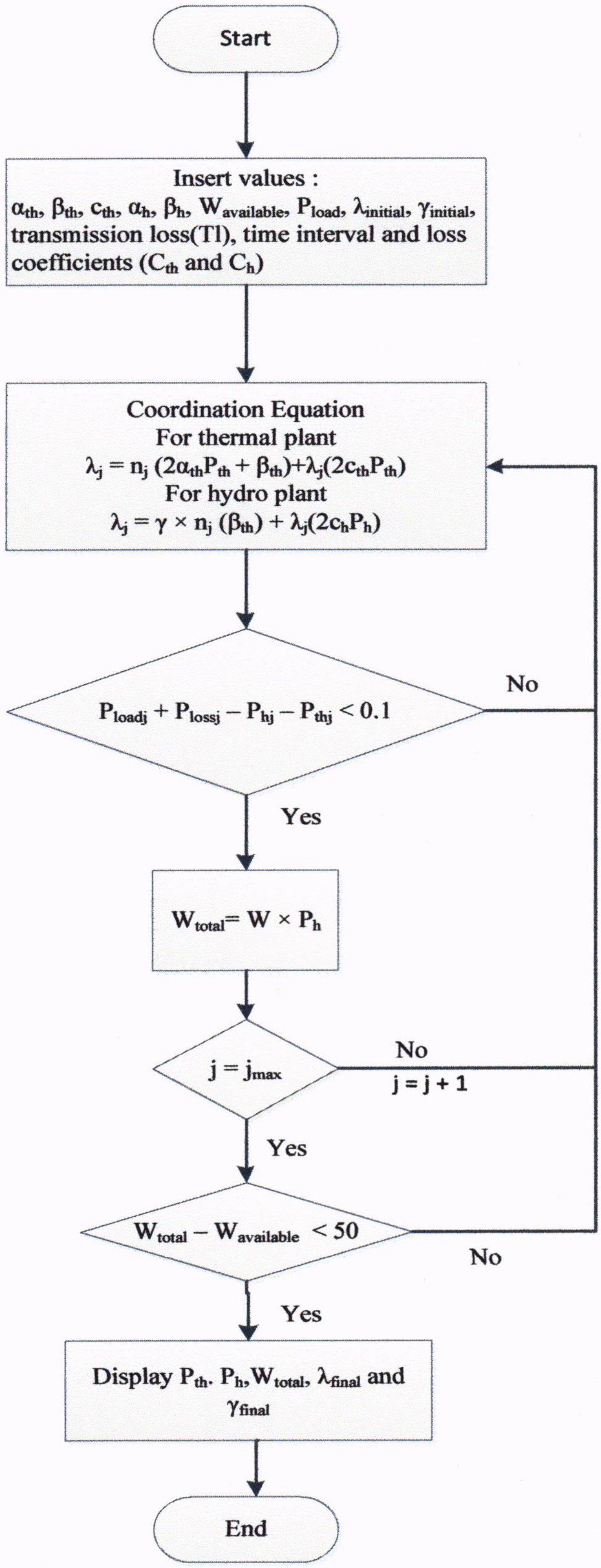

Figure 2: Flow chart to solve short term hydrothermal problem

B. The Developed Graphical User Interface

Figure 3 : Front page of the GUI

Figure 3 above shows the front page for graphical user interface. There are 3 buttons labeled as 'ENTER', 'INFO' and 'HELP'. 'ENTER' button directs the users to calculation for short term hydrothermal scheduling. Meanwhile, 'INFO' button give a short overview on short term hydrothermal scheduling and 'HELP' button gives some instructions in using the GUI.

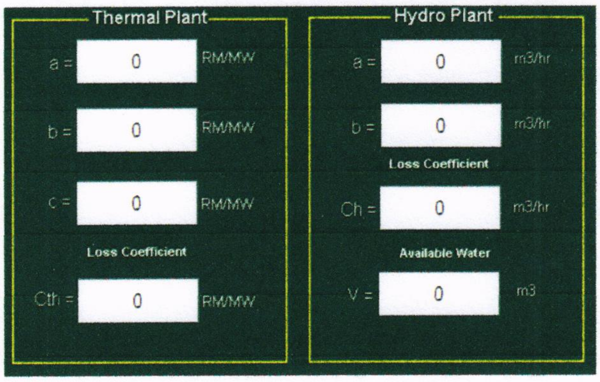

Figure 4 : Display for both thermal and hydro plant coefficients

The interface in Figure 4 above allows the users to insert the value of coefficients for each thermal and hydro plant. The users also can insert the present volume of water that available hydro plant. In this paper, the loss coefficients for both hydro and thermal are considered as 0.

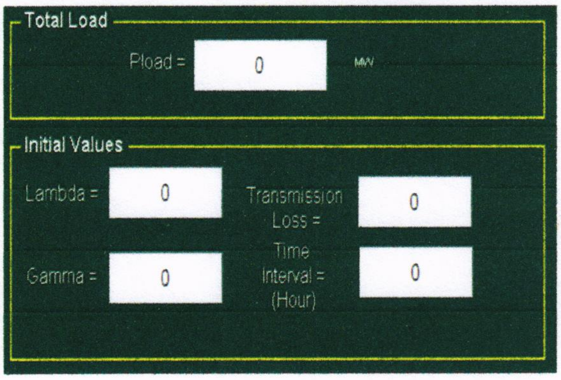

Figure 5 : Total load and initial values display

While on the interface in Figure 5, the users can insert the total load at specific time. For initial values, the transmission loss(Tl), initial incremental cost, $\lambda_{initial}$, initial gamma, $\gamma_{initial}$ and time interval in hours are defined as in Figure 5.

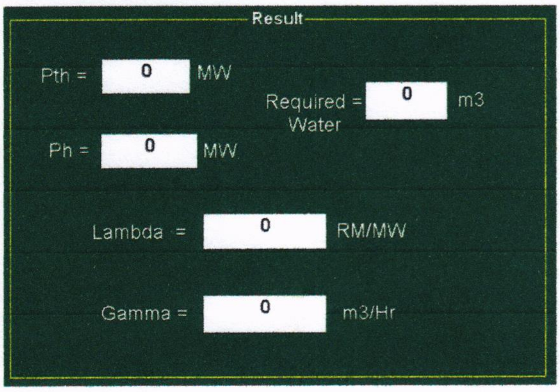

Figure 6 : Final Result

Figure 6 is for result displaying, where the users can obtained the final value of generated thermal power, P_{th}, generated hydro power, P_h, volume of water required, actual lambda, λ and actual gamma, γ are displayed. With all the known values, the users can compare them with self calculation and determine any differences between the interface and the user's calculation.

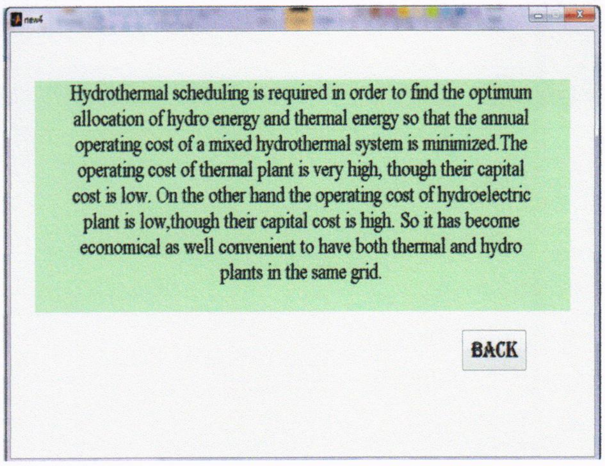

Figure 7 : Info Page On Short Term Hydrothermal Scheduling

Figure 7 shows the info page regarding the short term hydrothermal scheduling. This interface gives a short introduction to the users on short term hydrothermal scheduling problem. When the users press the 'BACK', the display will turn back to the front page.

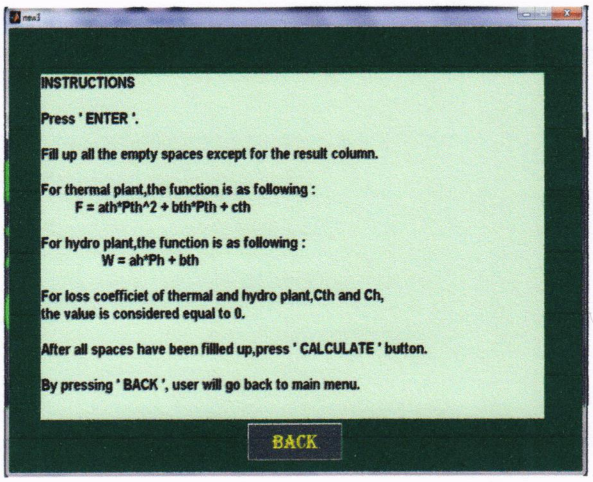

Figure 8 : Instruction On Using The Developed GUI

Figure 8 shows the instructions on using the developed GUI. This interface also provides the user with related equation on short term hydrothermal scheduling problem which in this case are the cost function for thermal plant and hydro plant.

IV. RESULTS AND DISCUSSIONS

A. Data

All the initial data in this paper is taken from literature[8]. All the data are shown in Table 1 and Table 2 below:

Table 1: Coefficient for Thermal Plant and Hydro Plant

	Thermal Plant	Hydro Plant
a	0.0002	6000
b	8	10000
c	1200	0

Table 2 : Others

Period (Hours)	12
Volume Of Water Available (m3)	32000000
Transmission Loss (Tl)	$0.0000045*P_h^2$
P_{load} (MW)	800
Gamma ($\gamma_{initial}$)	0.0016
Lambda ($\lambda_{initial}$)	9.6
Power tolerance , ε_1	0.01
Water tolerance, ε_2	50

B. Result generated in M file

For $j = 1$, $P_{load} = 800MW$

Table 3: Result Generated In M File

k	λ	γ	P_{th} (MW)	P_h (MW)	P_{total}
1	9.6	0.0016	400	0	400
2	10.1	0.0016	525	5500.55	5889.4
3	9.85	0.0016	462.5	2820.08	3246.79
4	9.725	0.0016	431.25	1428.16	1850.23
5	9.6625	0.0016	415.625	718.701	1132
6	9.63125	0.0016	407.813	360.516	767.744
7	9.64688	0.0016	411.719	539.898	950.306
8	9.63906	0.0016	409.766	450.28	859.133
9	9.63516	0.0016	408.789	405.416	813.466
10	9.6332	0.0016	408.301	382.971	790.612
11	9.63418	0.0016	408.545	394.195	802.04
12	9.63369	0.0016	408.423	388.583	796.326
13	9.63369	0.0016	408.423	388.583	796.326
14	9.63406	0.0016	408.514	392.792	800.612
15	9.634	0.0016	408.499	392.09	799.898

Based Table 3 above, for P_{load} = 800 MW, the best combination of thermal power, P_{th} and hydro power, P_h are at iteration k = 15. For Table 3, the generated thermal power, P_{th} is equal to 408.499 MW and generated hydro power P_h is equal to 392.09 MW. Basically, the combination of the thermal power generated and hydro power generated have only satisfied the power tolerance, ε_1 only. This can be seen in Table 3 when the lambda is equal to 6.34, the total generated power by thermal plant and hydro plant is almost equal to P_{load} in Table 2. The constant value of gamma, γ at 0.0016 indicate that the combination of thermal plant and hydro plant still not satisfy the water tolerance, ε_2. In order to obtain the best combination for both thermal plant and hydro plant, the combination of thermal plant and hydro plant must also satisfy the water tolerance, ε_2.

C. Simulation Result

All data in Table 1 and Table 2 were inserted into the developed GUI as shown in Figure 7 and Figure 8. Then, all the generated result displayed as in Figure 9.

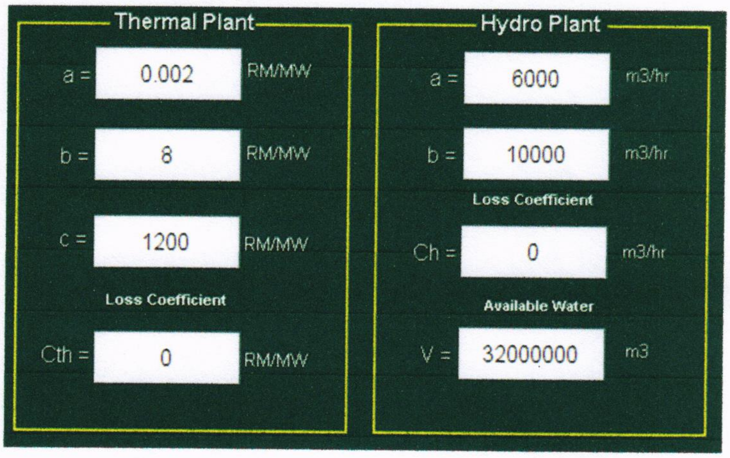

Figure 7 : Coefficients For Thermal Plant And Hydro Plant

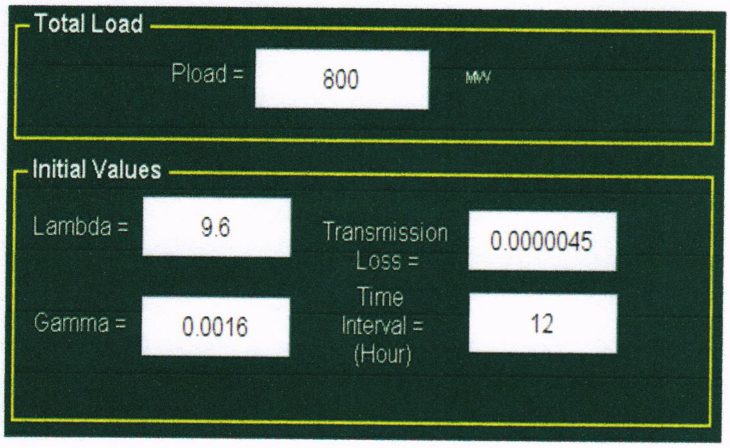

Figure 8 : P_{load} And Initial Values

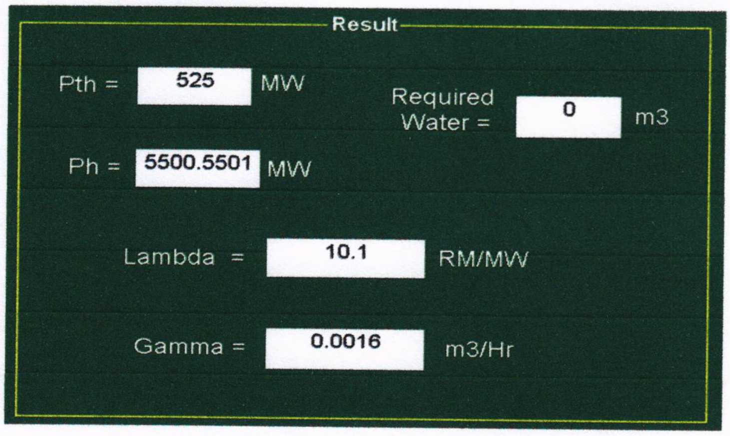

Figure 9: Result For P_{load} = 800MW

From the result display in Figure 9, the graphical user interface only displayed the generated thermal power, P_{th} and generated hydro power, P_h at iteration $k = 2$. According to the generated result in Table 3, at $k = 2$, the total power generated, P_{total} by thermal plant and hydro plant is equal to 5889.4 MW which is too high when compared to the desired load. This indicates that in graphical user interface callback has failed to satisfy ε_1 and ε_2. Thus, the volume of water that needed to generate desired hydro power cannot be determined.

V. CONCLUSIONS

In conclusion, a graphical user interface to solve short term hydrothermal scheduling problem has been developed in this project. The GUI shows the best combination of thermal plant and hydro plant in order to meet the load demand. The developed GUI can help to ease the calculation of short term hydrothermal scheduling by saving required time for the manual calculation. Hence, the possibility for errors to occur can be reduced to minimum level. This GUI also can be a useful and helpful educational tool to help the users for better understanding about short term hydrothermal scheduling.

VI. RECOMMENDATIONS

Some modification can be made to improve the appearance of the GUI. For example, more components can be added to the GUI. The animation of thermal plant and hydro plant also can be added to make the GUI more attractive. The programming for this GUI also can be improved in order to enable the GUI dealing with more complex problems.

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REFERENCES

[1] M. R. Babu, *et al.*, "An Hybrid Technique To Hydrothermal Scheduling."

[2] F. Kong and J. Wu, "Cultural algorithm based short-term scheduling of hydrothermal power systems."

[3] S. M. Esteban Gil, IEEE, *et al.*, "Short-Term Hydrothermal Generation Scheduling Model Using a Genetic Algorithm," *IEEE Transactions on Power Systems,* vol. 18, November 2003.

[4] G. G. N. Karady, K.A, "Improve learning efficiency by using general purpose mathematics software in power engineering," *IEEE Transactions on Power Systems,* vol. vol.18, pp. 979- 985, Aug. 2003.

[5] E. O'Neill-Carrillo, *et al.*, "Simulation Tools for Power Electronics Applications in Power Systems," 2002.

[6] D. Bică, *et al.*, "Power Engineering Education using NEPLAN software," 2005.

[7] B. H. Chowdhury and D. E. Clark, "COPERITE - Computer-Aided Tool for Power Engineering Research, Instruction,Training and Education," *Transactions on Power Systems,* vol. Vol. 7, November 1992.

[8] Chakrabarti, *et al.*, "Power System Analysis : Operation And Control."