AN OPTIMIZATION APPROACH TOWARD ONBOARD ENERGY MANAGEMENT SYSTEMS

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ABSTRACT

Optimization in the operation of electric power systems is an important task for both in land and onboard. The objective is to minimize operating cost index. Taking advantage of the scheme that onboard operator has the authority not only in the supply side but also in the demand size, an optimization approach toward onboard energy management system based on multiple attribute decision-making in the demand side is being developed. The model utilizes unit commitment and economic dispatch in the supply side and load management based on multiple attribute decision making in the demand side. As a part of the whole concept, this paper focused on the modelling and simulation of demand side. A user friendly demand side model consisting of Unit Commitment and Economic Dispatch is developed by using LabVIEW, Laboratory Virtual Instrument Engineering Workbench. Data taken from 3 units of Steam Power Plant are simulated. It is then eventually confirmed that 9% total cost saving can be achieved in the selected load demand range.

Key words*: optimization, unit commitment, economic dispatch, energy management systems*

INTRODUCTION

It is generally acceptable that the aplication of optimization methods in the operation of electric power system for both in land and onboard is a must. The objective is to minimize the operation cost index. Especially for onboard application, this issue becomes a more crucial task considering that there has been a significant increase in the use of electric propulsion systems as indicated by Charlton (1995) in which the electric power consumption is higher than that of in mechanical systems.

Dealing with the operation of electric power systems both for land-based and marine application, there are two components that should be faced with, the supply side and the demand side. The problem emerges when optimization methods are to be applied. The application of optimization methods is usually not integrated each other because they exist in the different world. The supply side belongs to electric companies; on the other hand, the demand side belongs to households or industries. This is true if land-based application is considered. However, onboard application has different features in term of authority. Operators have the authority to control both the supply and demand sides in a desired way because they produce electricity for their own.

Taking advantage of thisfeature, a concepts of optimization approach toward onboard energy management systems that simultaneously integrates supply and demand sides has been proposed (Suroso, *et al*., 2002; Masroeri and Suroso, 2002). In the supply side, economic dispatch and unit commitment are utilized to perform schedulling and optimum dispatched power for each generator, whereas load management based on multiple attribute decission is developed in the demand side (Suroso et al., 2005). As a part of this global concept, this paper will discuss the modelling of supply side management that is unit commitment and economic load dispatch.

Modelling

As previously stated that dealing with the operation of electric power systems both for landbased and marine application, there are two components that should be faced with, the supply side and demand side. This chapter discusses supply side modelling, involving unit commitment and economic dispatch. The models are developed by using LabVIEW.

All LabVIEW programs, or virtual instruments (VIs), have a front panel and a block diagram. The front panel is the graphical user interface of the LabVIEW VI. This interface collects user input and displays program input. The front panel can contain knobs, push buttons, graphs, and other controls and indicators.

The block diagram contains the graphical source code of the VI. In the block diagram, VI is programmed to control and perform functions on the inputs and inputs created on the front panel. The block diagram can include functions and structures from the built-in LabVIEW Libraries. It also can include terminals that are associated with controls and indicators on the front panel (LabVIEW, 1998).

LabVIEW is an OOP (object-oriented programming), a type of programming in which programmers define not only the data type of a data structure, but also the types of operations (functions) that can be applied to the data structure. In this way, the data structure becomes an object that includes both data and functions. In addition, programmers can create relationships between one object and another. For example, objects can inherit characteristics from other object.

One of the principal advantages of object-oriented programming techniques over procedural programming techniques is that they enable programmers to create modules that do not need to be changed when a new type of object is added. A programmer can simply create a new object that inherits many of its features from existing objects. This makes object-oriented programs easier to modify. These are the reasons why LabVIEW is chosen to develop the models.

The unit commitment (UC) is the problem of determining the schedule of generating units within a power system (Wood and Wollenberg, 1996). Given that there are a number of generating units that satisfy the expected demand, the UC determines which generating unit should be committed or decommitted in order to provide the optimum operating cost.

The generic UC problem can be formulated as an optimization problem. The objective functions are the fuel and start-up costs of the generating units, which are expressed below (Huang, 1999).

Min: Cost (K) = min

$$\sum_{i=1}^{n}\sum_{j=1}^{l}\left(K_{ij}\,F_i(P_j) + S_i K_j\,(1-K_{i,j-1})\right) \quad (1)$$

where Cost(·) is the cost function of the thermal generation scheduling problem, $F_i(\cdot)$ is the fuel cost function of unit i, K_{ij} is the on/off status of unit i at hour j, P_{ij} is the i_{th} unit generation output at hour j, S_i is the start-up cost of unit i, K is the decision matrix of K_{ij} variables, n is the number of generating units, and l is the number of hours in the study period. For the formulation of fuel cost function, a second-order polynomial is adopted as follows:

$$F_i(P_j) = Cp_j^2 + Bp_j + A_i = 1,\ldots, n\ldots \quad (2)$$

where A, B, and C are cost coefficients.

The first constraints is the electric power balance equation

$$\sum_{i=1}^{n} K_{ij}P_j = PD_j \qquad j = 1, \ldots, l. \quad (3)$$

where PD_j is the electric load demand at hour j.

The second constraint is the output limits of generating unit

$$P_{i,\min} \le P_j \le P_{i,\max} \quad i = 1, \ldots n; j = 1, \ldots l \quad (4)$$

where $P_{i,min}$ is the minimum output and $P_{i,max}$ is the maximum output power of the generating unit i.

Unit Commitment modeling utilizes Priority List method. The block diagram and front panel can be seen on Figure 1 and 2 respectively.

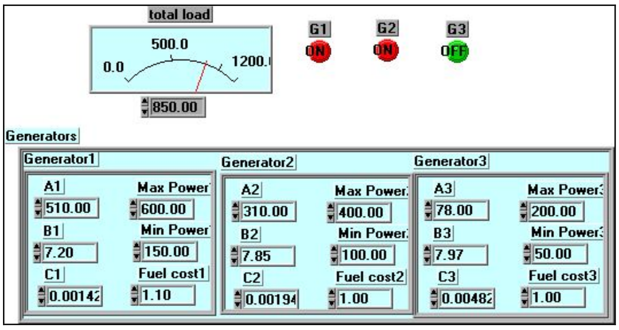

Figure 1. The Front Panel of UC Model

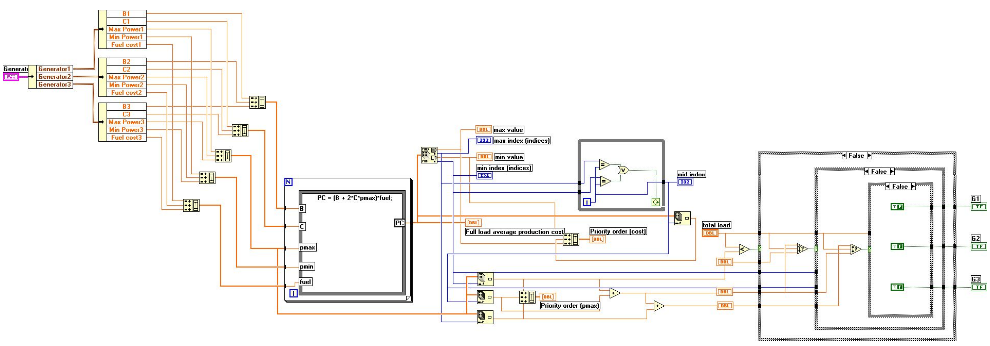

Figure 2. The Block Diagram of UC Model

Power generation dispatch, which is usually termed as Economic Dispatch (ED) problem, assumes that there are N units already connected to the systems. The purpose is to find the optimum operating policy for these N units (Wood and Wollenberg, 1996).

The ED problem can also be expressed as an optimization problem. The objective function, F_t, is equal to the total cost for supplying the indicated load. The problem is to minimize F_t.

$$\text{Min: } F_t = F_1 + F_2 + F_3 + \ldots\ldots + F_N$$

$$= \sum_{i=1}^{N} F_i(P_i) \quad \ldots\ldots (5)$$

The constraint on the operation of this system is that the sums of the output powers must be equal the load demand.

$$\phi = 0 = P_{load} - \sum_{i=1}^{N} P_i \quad \ldots\ldots (6)$$

The second constraint is the power output of each unit must be greater than or equal to the minimum power permitted and must also be less than or equal to the maximum power permitted.

$$P_{i,\min} \le P_i \le P_{i,\max}$$

The Front Panel and Block Diagram of Economic Dispatch model are illustrated in Figure 3 and 4 respectively.

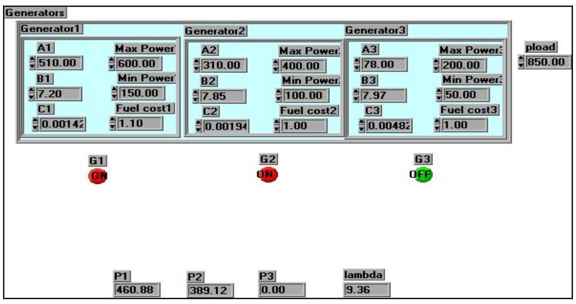

Figure 3. The Front Panel of ED Model

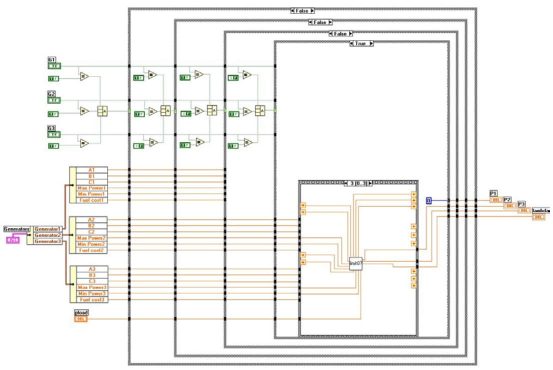

Figure 4. The Block Diagram of ED Model

Then, a model of energy management systems (EMS) is developed by combining the UC and ED models. The front panel and block diagram of the model are illustrated in Figure 5 and 6 respectively.

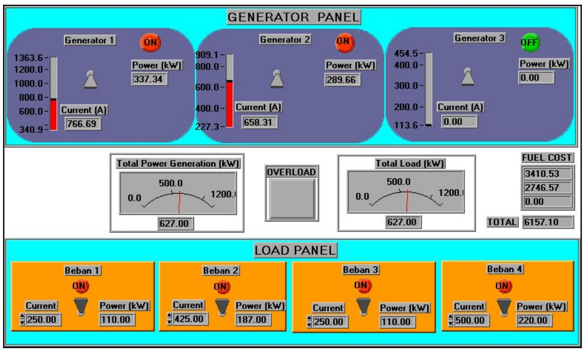

Figure 5. The Front Panel of EMS Model

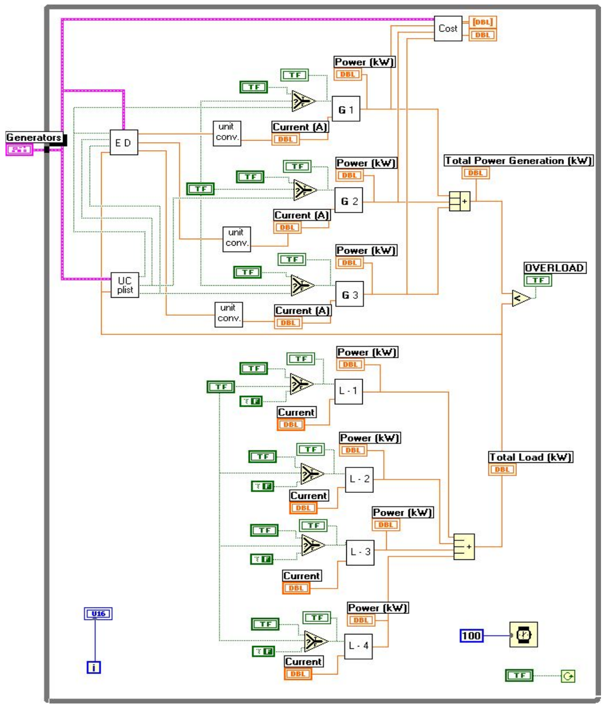

Figure 6. The Block Diagram of the EMS Model

As can be seen in the Figure 5, the EMS model is made up Generator Panel, consisting of three generator units and Load Panel, containing four load units. Between these two panels, total power generation and total load meter are situated.

The model can be simulated by varying current in each load unit which has been turned on, indicated by red-colored display. This variation is accumulated at the total load meter which is accounted as load demand. Responding to this load demand, the UC model executes which generator should be on or off. Then, the ED model will dispatch the amount of power for each committed generator.

Simulation and Discussion

Fuel consumption and dispatched power data taken from GrkU#1, GrkU#2, and GrkU#3 at PT. PJB Gresik are regressed by using SPSS Ver. 12.0 yielding second order polynomial input-output equations as shown in the Table 1.

Table 1. The Characteristic Equation

Unit	Input-output equation
Grk U#1	2 × 10-6 P12 + 2.827 P1 + 5692
Grk U#2	2 × 10-6 P22 + 1.846P2 + 561900
Grk U#3	1 × 10-6 P32 + 5.869 P3 + 12605

The A, B, and C coefficients of the equation for each generating unit become inputs for the front panel in the Figure 3. It is then simulated for the load range between 6466 and 8959 MW. In this simulation, it is assumed that the maximum and minimum powers are 500 MW and 4800 MW respectively. It is also assumed that the fuel price is 1 R/liter. In this case a nameless fictional monetary unit R is used to avoid leaving false impressions about the actual value of the methods (Wood and Wollenberg, 1996). The result of the simulation is represented in the Table 2.

Table 2. Simulation Result

No	Load (MW)	Dispatched Power P1	P2	P3	Cost (kR/h)
1	6466	1935	2180	2349	23868
2	6768	2010	2256	2500	25107
3	6976	2062	2308	2604	25961
4	7168	2110	2356	2700	26748
5	7364	2159	2405	2798	27552
6	7601	2219	2464	2917	28525
7	7946	2305	2550	3089	29940
8	8209	2371	2616	3221	31019
9	8517	2448	2693	3375	32283
10	8618	2473	2718	3425	32697
11	8718	2496	2743	3475	33108
12	8829	2526	2771	3531	33563
13	8959	2558	2803	3596	34096

From Table 2, it can be obtained that cost is increasing as the load increase. With the same load range, the cost for the real data is also calculated. The result is visualized in the Table 3. From these two tables, the differences between cost derived from simulation and real data is plotted in the Figure 7. It can be seen that cost savings around 9% is achieved by the application of optimization. It is important to note that all three generating units are committed in the whole operation. This is because, regarding the data taken, their status are 'must run' in the whole operations.

Table 3. Cost Calculation from Full Scale Data

No	Load (MW)	Dispatched Power P1	P2	P3	Cost (kR/h)
1	6466	1702	1729	3035	26395
2	6768	1780	1779	3209	27729
3	6976	1788	1797	3391	28853
4	7168	2007	2023	3138	28405
5	7364	1845	1852	3667	30736
6	7601	1941	1951	3709	31437
7	7946	2032	2017	3897	32919
8	8209	1998	2007	4204	34606
9	8517	2108	2101	4308	35701
10	8618	2142	2219	4257	35716
11	8718	2118	2105	4495	36834
12	8829	2171	2156	4502	37119
13	8959	2213	2204	4542	37561

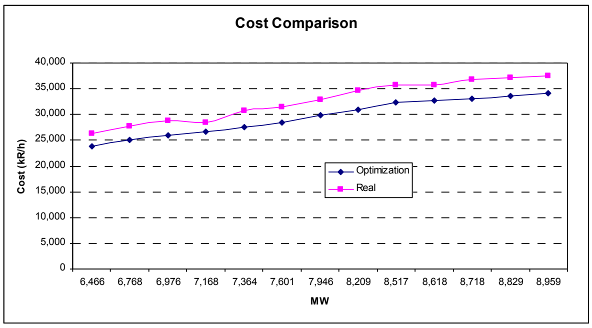

Figure 7. The Cost Comparison

CONCLUSSION

This paper presents modelling of a user friendly model for supply side management systems. The model consists of unit commitment and economic dispatch developed by using LabVIEW. Then, the model will be fully integrated with the demand side model to develop global scenario of onboard energy management system which is being developed in The Department of Marine Technology, ITS Surabaya. Data taken from three units of steam power plants are simulated for the load demand range between 6466 and 8959 MW to obtain the committed generator, dispatched power, and operation cost. The results show that an optimal value of dispatched power for each generating unit has been found. In addition, an average of nine percent of total cost saving derived from optimization has been achieved. It can be concluded that the model developed by LabVIEW provides the desired result.

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