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# Unit Commitment using Embedded Systems

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**Abstract**

Unit commitment problem helps in deciding which electricity generation unit should be running in each period so as to satisfy a predictably varying demand for electricity. Unit Commitment enables uninterruptible power to be delivered to consumers using the principle of minimum operating cost. In this paper a laboratory prototype for unit commitment is developed using embedded systems. In this work, the unit commitment problem is solved using dynamic programming approach. The generators are switched ON and OFF on a priority basis to minimize the total operating cost of the generating units. An Embedded Development Kit(EDK) is used for the prototype which supports micro framework technology. The laboratory prototype is tested for various combinations of generating units.

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*Keywords:* Embedded Development kit; Dynamic programming; Unit commitment.

## 1. Introduction

Unit commitment problem is used to determine the generating units that should operate for a particular load. This problem is important for thermal plants compared to other types of generation such as hydro since their operating cost and start-up times are negligible their on-off status is not important. A straight forward but highly time consuming way of finding the most economical combination of units to meet a particular load demand, is to try all possible combinations of units that can supply this load; to divide the load optimally among the units of each combination by the use of co-ordination equations, so as to find the most economical operating cost of the combination; then to determine the combination which has the least operating cost among all the connected generators. Also Gas turbine plants are relatively fast in operating. Sudden switching is also possible with PV plants.

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Dynamic programming algorithm is a method in which considerable computational savings can be obtained. The algorithm would systematically evaluate a large number of possible decisions in minimizing the overall cost in a multi-stage scheduling problem. Unit commitment is implemented using embedded systems. DOT net framework is used to implement dynamic programming. The .NET framework supports multiple programming languages in a manner that allows language interoperability, whereby each language can utilize the code written in other languages. In [1] mixed integer programming formulations for unit commitment problem is done . In this paper, the simulation results for realistic instances that range in size from 10 to 100 units over a scheduling period of 24 hours is discussed. In [2], the cost impact of various demand response modeling on unit commitment and dispatch in a day-ahead market regime has been investigated. In [3] Quasi-Oppositional Teaching Learning Based Algorithm (QOTLBA) is solved using thermal unit commitment problem. In [4] Dynamic Programming Approach for Large Scale Unit Commitment Problem is discussed . In paper [5] Review on methods of generation scheduling in electric power systems is discussed. In [6] a new method is developed for scheduling units with ramping constraints. In [7], a profit based Unit Commitment for the Competitive Environment is discussed and analysed. In [9 ] a review of an optimal thermal generating unit commitment is discussed. In [10], an ANN based controller for reactive power compensation is implemented. In [13], a laboratory prototype for demand side management is developed .

In this paper, a laboratory prototype for unit commitment is developed. Section 2 deals with the unit commitment problem. Section 3 highlights the use of Dot net technology. The details of embedded development platform is brought out in section 4. The dynamic programming approach is described in section5. Section 6 explains the real time scenario. The results and conclusions are presented in section 7.

## 2. Unit Commitment

Unit Commitment problem is applied to a sample system having four Generating units connected to load which is shown in Fig. 1. The minimum, maximum capacity, cost curve parameters are shown in Table 1 [8]. Let the load changes be in steps of 1 MW.

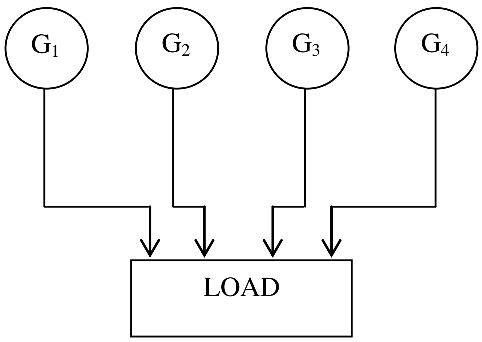


Fig. 1. Sample system with four generating units connected to load.

The operating cost of each generating unit is given by equation (1). The combination of generators that gives the minimum operating costs has been found using dynamic programming approach. The recursive relation is then obtained as in equation (2) .

$$f_n(y) = \frac{1}{2} a_n P_{G_n}^{\;2} + b_n P_{G_n} \tag{1}$$

$$F_n(x) = \min\{f_n(y) + F_{(n-1)}(x-y)\} \tag{2}$$

where,

$F_n(x)$ – minimum operating cost for a combination of "n" generators feeding "x" MW
$f_n(y)$ – operating cost of the nth generator feeding "y" MW
$F_{n-1}(x-y)$ – minimum operating cost for a combination of "n-1"generators feeding "x-y" MW.

Table 1 : Generating unit parameters

| Unit Number | Capacity (MW) | | Cost curve parameters | |
|---|---|---|---|---|
| | Minimum | Maximum | a (Rs/MW$^2$) | b(Rs/MW) |
| 1 | 1.0 | 12.0 | 0.77 | 23.5 |
| 2 | 1.0 | 12.0 | 1.6 | 26.5 |
| 3 | 1.0 | 12.0 | 2.00 | 30.0 |
| 4 | 1.0 | 12.0 | 2.5 | 32.0 |

Table 2: Truth table for Unit commitment

| Load Range | Unit Number | | | |
|---|---|---|---|---|
| (MW) | 1 | 2 | 3 | 4 |
| 1-5 | 1 | 0 | 0 | 0 |
| 6-13 | 1 | 1 | 0 | 0 |
| 14-18 | 1 | 1 | 1 | 0 |
| 19-48 | 1 | 1 | 1 | 1 |

where, 1= unit running ; 0= unit not running

Using the above function, an unit commitment table has been obtained as shown in Table 2. It acts as a operating sequence for implementation in the EDK using Dot net technology. When the load range is less than 5MW, generator G1 is switched ON. When the load varies from 6 MW to 13 MW, generators G1 and G2 are switched ON. The generators G1, G2 and G3 are switched ON when the load variation is from 14MW to 18MW. When the load varies from 19MW to 48MW all four generating units are switched ON.

## 3. Dot Net Technology

The Microsoft .NET Framework is a software that can be installed in computers running on Microsoft operating systems. The .NET Framework supports multiple programming languages in a manner that allows language interoperability, whereby each language can utilize code written in other languages[12];

## 4. Embedded Development Kit (EDK)

The EDK features EMAC's iPac-9302 Single Board Computer (SBC) with the .NET Micro Framework already on board as shown in Fig.2. The iPac-9302 features an ARM9 processor with a variety of IO to meet the needs of any application. The EDK is a multi-use solution that can be used to develop a variety of embedded applications such as robotics, shipment tracking, industrial controls, security systems, Point of Service applications, and much more. The iPac-9302 is a production-quality board that can be embedded, as-is, into a final product; or it can be used as a reference design for a custom end product[12].

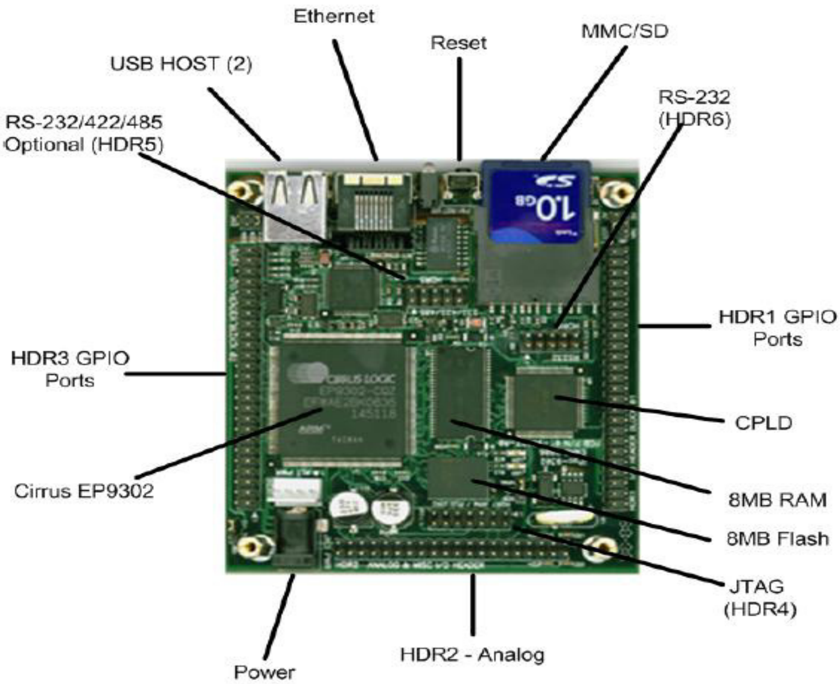


Fig. 2 iPac 9302

## 5. Unit Commitment Algorithm

1. Start

2. Assign the cost curve parameters a and b of each generator as given in Table.1.

3. In the the iPAC 9302 board, assign pins PY7,PY5,PY2,PY0 as output pins to which the four generators are connected respectively.

4. Read the load.

5. Calculate the operating cost for all the combination of generators.

6. The combination for which the total operating cost is minimum is found.

7. The pins (for which the generators are ON) are set HIGH and the remaining pins (for which the generators are OFF) are set LOW.

8. If there is any change in the load, repeat the procedure from step 4.

## 6. Real Time Scenario

The computer is placed in the Dispatch centre as shown in the Fig.3 . The Dispatch centre collects the future load demand data. An EDK (Embedded Development Kit) consisting of the Single Board Computer iPAC 9302 is placed at the control centre. The Generators are connected to the EDK. A software program is loaded into the EDK which follows a Unit commitment algorithm. The computer in the Dispatch centre controls the EDK through an RS232 Cable . When the EDK receives instructions from the computer for Unit commitment, the software program is executed. The software program calculates the best combination of generators which has the minimum operating cost according to the Unit commitment algorithm.

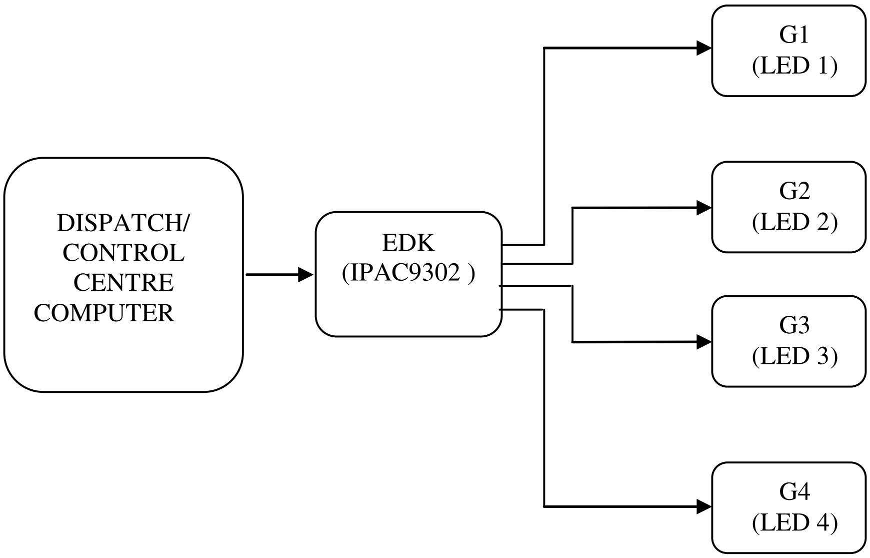


Fig. 3 Dispatch centre connected to the generating units.

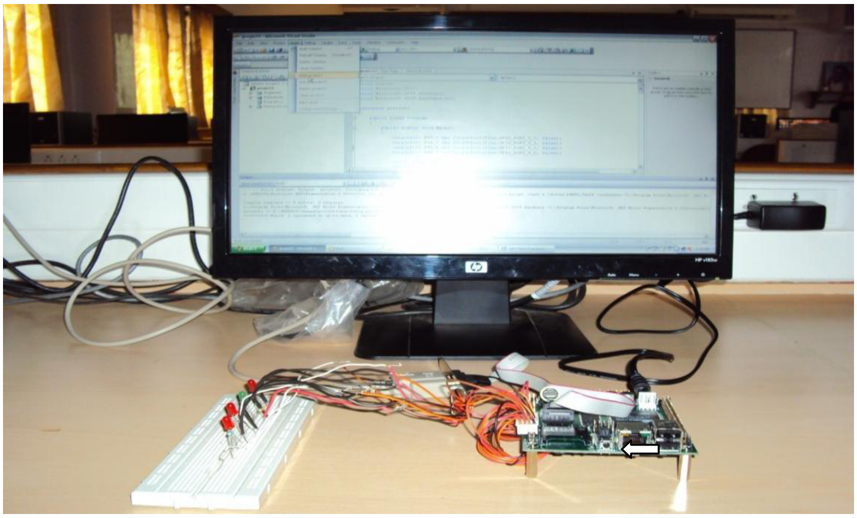

Fig.4 Snap shots of the hardware setup

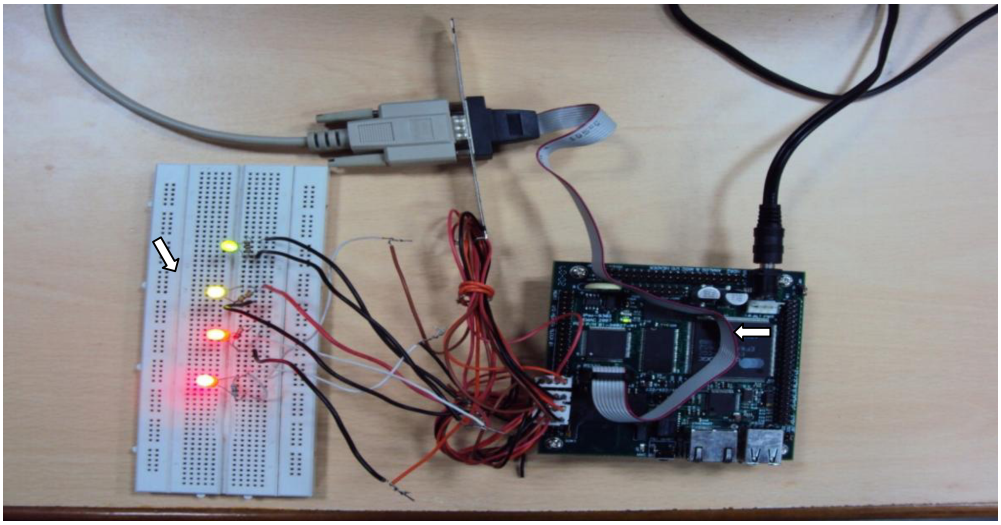

Fig.5 All four Generating Units are ON.

The software program calculates the best combination of generators which has the minimum operating cost according to the Unit commitment algorithm. The snap shot of the hardware setup is shown in Fig. 4 and Fig. 5. The LED's are replaced by relay driver circuits and the combination of generating units are verified. The circuit diagram for the relay driver circuit is shown in Fig.6. The load combination of 15 MW is given in the computer and verified for three combinations of generating units. The snapshot of generating unit with relay driver circuit is shown in Fig.7.

## 7. Conclusion

In this work, a laboratory prototype is developed to demonstrate the working of unit commitment. Dynamic programming algorithm has been applied to four generating units and is successfully implemented in Dot net board. The results were checked for all combinations of generating units.The work can be extended to a set of laboratory generating units and the switching on/off can be implemented using embedded system.

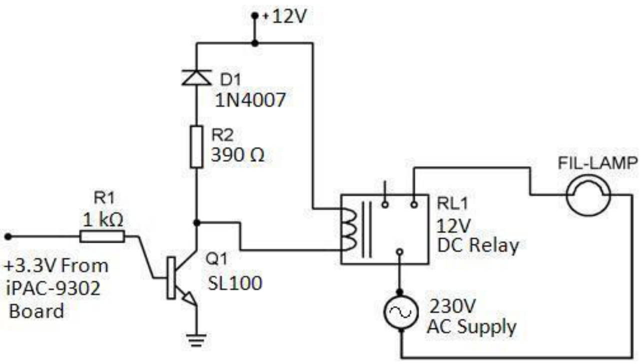


Fig.6 Circuit diagram of relay driver setup

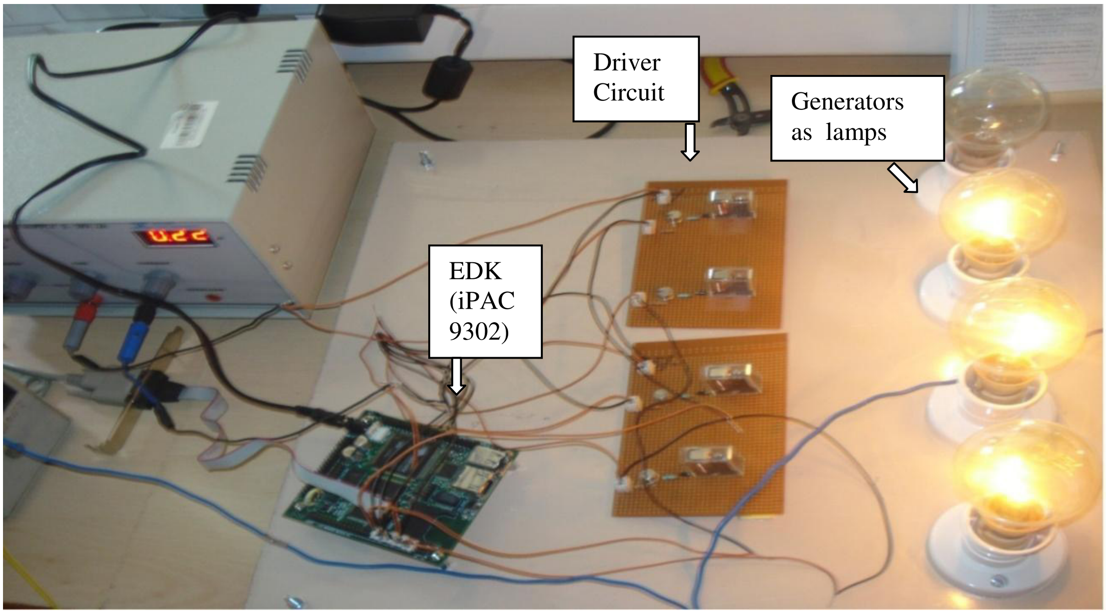


Fig.7 Embedded board with lamp load

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