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SELECTION OF OPTIMAL AREAS OF FEED WATER HEATERS USING DYNAMIC PROGRAMMING

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Abstract: The design objective could obviously to maximize the efficiency of production or to minimize the cost of production, in most engineering design activities. Optimization is central to any problem involving design making, whether in economic or engineering. The choice is governed by our design to make the most feasible design and the dynamic programming technique, when applicable, represents or decomposes a multi stage decision problem as a sequence of single stage decision problems.

I. INTRODUCTION

The area of optimization has received enormous attention in recent years, primarily because rapid progress in computer technology. Optimization theory and methods deal with the selecting the best alternative in the sense of given objective function [1]. In this subject we will describe the uniqueness of dynamic programming as a method of optimization solution for many problems. The key feature of dynamic programming is that after an optimal policy has been determined then an intermediate state of final state [2]. As an Example we will take a problem related to power plant then we will analysis areas that give us maximum saving in steam turbine power stations that operating on organic fuel. The main thermal units at steam turbine power station are steam boiler and steam turbine. The water supplied into steam boiler is called feed water. Feed water is preheated to the saturation temperature and equipped to the boiler by a feed water pumps through high pressure water heater and then into steam boiler. The feed water in high pressure heaters are heated by steam taken off from the turbine, this is called regenerative water heating.

This method increases the efficiency of steam turbine plant and decrease the heat loss in the condenser. The steam coming out of the turbine is condensed and the condensate is feed back to the boiler as feed water. It is necessary to heat water before feeding it back to the boiler for the following reasons.

- Feed water heating improves over all plant efficiency.
- The dissolved oxygen and carbon dioxide which would otherwise cause boiler corrosion are removed in the feed water heater.
- Thermal stress due to cold water entering the boiler drum is avoided.
- Quantity of steam produced by boiler is increased.
- Some other impurities carried by steam and condensate due to corrosion in boiler and condenser are precipitated outside the boiler.

In large modern plants heaters bleed steam from the main turbine, and use it for feed water heating the feed water is heated put under pressure and then further heated so that its temperature and pressure exceeds that of water in the boiler. It is the job of the Designers to allocate the thermal areas between the heaters such that the operating costs are the minimum and the saving are maximum this can be achieved by using Dynamic programming method. Dynamic programming is a non linear optimization technique which is applicable to a wide class of multi stage decision problems $0 \rightarrow \infty$

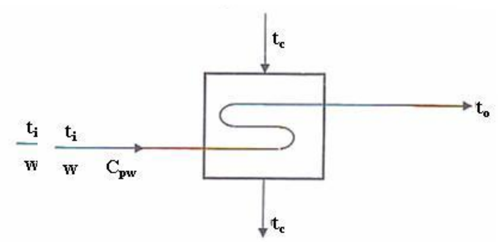
Mechanical engineers design mechanical components for the purpose of achieving either a minimum manufacturing cost or a maximum component life. A design problem usually involves many design parameters, of which some are highly sensitive to the working of the design [4]. It is based on the principle of optimality it should be noted that dynamic programming involves the implicit evolution of all possible paths. Therefore it is always achieves the global optimum. It's clearly a very powerful technique for problems which can be organized into a suitable form.

It is a method of optimization that is applicable either to stage processes or to continuous functions that can be approximated by staged processes.

Optimization is the act of obtaining the best result under given circumstances. In design construction, and maintenance of any engineering system, engineers have to take many technological and managerial decisions at several stages. The ultimate goal of all such decisions is to either minimize the effort required or maximize the desired

Benefit [5]. Optimization is divided into several parts depending on the complexity of the geometry involved. Then example problem s and general problems are presented for parameter optimization and optimal control [6]. When an optimization problem modeling physical system involves only one objective function, the task of finding the optimal solution is called single –objective optimization. When an optimization problem involve more than one objective function, the task of finding one or more optimum solutions is known as multi –objective optimization[7]. The dynamic programming technique suffers from a major drawback, known as the curse of dimensionality. However, despite this advantage, it is very suitable for the solution of a wide range of complex problems in several area of decision making [9]. In many engineering situations the problem consists of analysis of discrete stages, and have the calculus of variations would only approximate the result. The first table in the dynamic programming solution is a necessary routine, but it is the second table that dynamic programming becomes effective and difficult. The solution by dynamic programming of apparently constrained problem is shown in the optimization of feed heating. Heating the boiler feed water with extraction steam improves the efficiency of steam power cycle and is a common practice in large central power stations. Some plants use more than half a dozen heaters which draw extraction steam at as many different pressures. That feed water heaters improves the efficiency of a cycle be shown by a calculation of specific case.

But a qualitative explanation way provides a better sense of this improvement. The steam power cycle approximately 3j of heat is supplied at the boiler for every joule of work at the turbine shaft.
The difference of 2j is the amount rejected at the condenser which usually represents a loss. The proposal to try to use some of the heat rejected at the condenser for boiler water heating is (loomed because if we tried, for example to heat the feed water with exhaust steam from the turbine, there would be no temperature difference between tile exhaust steam and the feed water to provide the driving force for heat transfer. Extraction steam, how ever, has a higher temperature than exhaust steam and can be used for heating. Concentration on l kg of extraction steam leaving the boiler, we find it performs some work in the turbine before extraction and then uses the remainder of its energy above saturated liquid at the condensing temperature to heat the feed water. In effect, then all the heat supplied to the kilogram of steam in the boiler is eventually converted into work. The practice of feed water heating by extraction steam raises the effectiveness of the cycle compared to rejecting 2j of boiler heat per joule of work. It is further to be expected that the high-pressure steam is more valuable than the low pressure steam because the steam extracted at high pressure would have been able to deliver additional work at the turbine shaft. Let us start our example to see how we can use dynamic programming as a method of optimization solution for such kind of problems. For a heat exchanger of known characteristics equation (i) can be used to compute the outlet temperature of the fluid that does not change phase when it’s entering temperature and the temperature of the boiling and condensing fluid tc are known.
Fee



$$t_0 = t + (t_c - t_i)(1 - \exp(-UA / WC_{pw})) \quad (i)$$

$$Q = m_w C_{pw} (t_0 - t_i) x 10^{-6} GW \quad (ii)$$

$$Saving = (Wfw - Wes) Q \quad (iii)$$

Feed Water Treatment
Boiler make up water to the extent 1.5-2 per cent of the total flow rate is required to replenish the losses of water through leakage from fittings and bearings, boiler blow down, escape with non-condensable gases in the deaerator, turbine glands, and other causes. This make-up water needs to be treated prior to feeding it to the boiler for,

- Prevention of hard scale formation on the heating surfaces.
- Elimination of corrosion,
- Control of carry-Over to eliminate deposition on super heater tubes,
- Prevention of silica deposition and corrosion damage to turbine blades.

External Treatment
The first step of pre-treatment of boiler feed water is clarification, in which the water is chlorinated to prevent biofouling of the equipment. The suspended solids and turbidity are coagulated by adding special chemicals (like aluminum sulphate, $Al2(SO4)3$) and agitated [8]. The coagulated mater settles at the bottom of the clarifier and is removed. If the turbidity of clarified effluent is high, positive filtration is needed. Both gravity filters and pressure type filters are used, but the latter is preferred. A granular medium like sand is commonly used for filtration. The pressure difference across the filtering medium is an indication of solid accumulation. When it reaches a given limit, the solids are removed from the bed by backwashing. Further filtration by activated carbon can absorb organics and remove residual chlorine from the chlorination process. The dissolved salts of calcium and magnesium give to water a quality called hardness. Hardness is characterized by the formation of insoluble precipitates or curds with soaps, and is usually measured with a standard soap test. All natural waters are hard and contain scale-forming impurities which are mainly the salts of calcium and magnesium in the form of carbonates, bicarbonates, chlorides and sulphates. The hardness is expressed in ppm of dissolved salts. Softening of water, i.e. removal of hardness from water can be done by lime-soda process, zeolite process and demineralization.

Problem Approach
An economic analysis has determined that a total of 1000 m2 of heat transfer area should be used in the four feed water heaters shown in the figure. This 1000m2 can be distributed in the four heaters in 100-m2 increments. The over all heat transfer coefficient of all heaters is 2800w/ (m2.K). The cost of heat at the boiler is 60cents/GJ, and the worth of the extraction steam determined by thermodynamic calculation is worth of the extraction steam determined by thermodynamic calculation is listed in table no1.The flow rate of feed water is 100 kg/s. Use dynamic programming to determine the optimum distribution of the area figure 1.

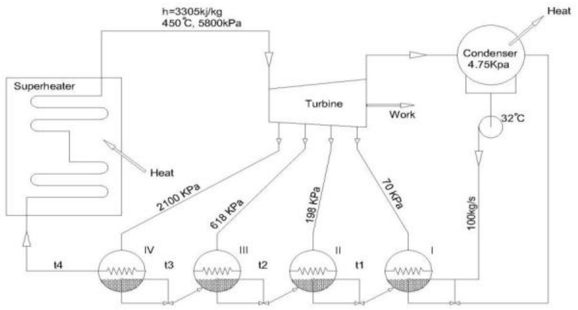


Figure 1: Selection of optimum areas of feed water heaters

II. NUMERICAL ANALYSIS

Before beginning the solution it may be instructive to try to predict the nature of the optimal solution. It is desirable to use the lowest-cost steam

Table 1: Extraction Steam Data

Extraction and heater number	Saturation Temperature (C°)	Worth of extraction Cent/GJ
1	90	0.23
2	120	0.28
3	160	0.38
4	215	0.47

Possible, which would suggest a large area in stage 1, but each additional unit of area in that stage is less effective than the previous unit area because the temperature difference between the steam and feed water is less. This problem is apparently constrained because the total area is specified, but it can be converted into the unconstrained form by using as the state variable the total area committed.

Table 2 shows the outlet temperatures from stage I for various areas in that stage. As is typical of dynamic programming, this first table is routine. The temperatures are computed by using equation (1) for condenser, and the saving is the value of the heat saved at the boiler less the cost of extraction steam used.

Table 3 uses as the state variable the total area committed in the first two stages. If, for example, 1000m' is available for the first two stages, the optimum distribution is to allot 400m' in the first stage and 600m''' in the second, resulting in a saving of S 1.285 per second.

Table 4 shows various area distributions in the first three stages.

Table 2: Extraction Steam Data For Stage I

Total area (m^2)	Area for Stage I (m^2)	t_1 C°	Q [GW]	Saving Cent/second
0	0	32.00	0	$.000
200	200	74.76	0.0179164	$.663
400	400	86.00	0.0226241	$.837
600	600	88.95	0.0238611	$.883
800	800	89.72	0.0241862	$.895
1000	1000	89.93	0.0242716	$.898

Table 3: Extraction Steam Data For Stage I & II

Total Area m^2	Area for II (m^2)	t2 (C˚)	Saving ($/second)
0	0	32.00	$.000
100	0	60.27	$.438
	100	74.76	$.575*
200	0	74.76	$.663
	100	89.38	$829
	200	93.88	$.870*
1000	0	89.93	$.898
	200	112.04	$1.194
	400	117.86	$1.270
	600	119.38	$1.285*
	800	119.78	$1.267
	1000	199.89	$1.178

Table 4: Extraction Steam Data For Stage I, II & III

Total Area (m^2)	Area for III (m^2)	t3 (C˚)	Saving ($/second)
0	0	32.00	$.000
100	0	74.89	$.575*
	100	94.39	$.575*
200	0	96.88	$.870
	100	116.37	$957*
	200	126.37	$.870
1000	0	119.38	$1.285
	200	149.14	$1.548
	400	157.02	$1.598*
	600	159.13	$1.566
	800	159.70	$1.449
	1000	159.84	$1.178

III. CONCLUSION

When optimizing a system that consists of a chain of events or components when the output condition from one unit forms the input to the next, dynamic programming should be explored. In large problems the amount of calculation may be extensive, even though it represents only a fraction of the effort of conducting an exhaustive exploration.

The systematic nature of dynamic programming lends itself to development of a computer program to perform the calculations. The major challenge usually appears in setting up the tables, and especially in identifying the state variable. From tables, we indicate for distributing 1000m2 area in 4 heaters in 100 m2 increments to get total saving of 1.804 $ per second. Firstly 1000m2 is distributed on one heater area, (A1) to get the saving. Secondly 1000m2 is distributed between A1 and A2 and gets the total saving. Thirdly 1000m2 is distributed between A1, A2 and A3 to get the total saving. For each area we calculate the saving in each area and total saving for all distributed areas. Finally, we can see from table No. 5 where the full area of 1000m2 is committed indicates that the optimum distribution of area is 100, 300, 300, 300 for a total saving of S 1.804 per second.

Nomenclature

ti: outlet feed water temperature (C)
tc: Inlet feed water temperature (C)
t,: bleeding steam temperature (C)
W: feed water mass flow kg/s.
U: thermal conductivity coefficient kw/m2/k.
A: Area of heating surface m2
Wfw: 60 cent/GJ cost of heat at boiler.
Wes: Extraction steam cost.
Cp: Specific Heat at constant pressure = 4.19(KJ/Kg/K)
U: 2.8 (Kw/m2/K)
Mfw: 100 (Kg/S)

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