MODELLING AND SIMULATION OF THE COMBINED HEAT AND POWER PLANT OF A REAL INDUSTRIAL SYSTEM

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ABSTRACT

This paper presents a mathematical model of a Combined Heat and Power (CHP) plant. In this study, operating of CHP which produce electricity and heat that is developed for transferring efficient energy at the same system are discussed. Generated electricity control is examined by acquiring mathematical model of selected system

Industrial cogeneration system that is modelled is connected to auxiliary devices. Such systems either sell electricity to a utility or buy electricity from the utility. Auxiliary devices connected to cogeneration systems include a compressor, combustion chamber and gas turbine used in conjunction with a Heat Recovery Steam Generator(HRSG) connected to the exhaust path

I. INTRODUCTION

Recently, energy consumption is getting increased fastly. Although demand of energy is getting increased, the sources of energy aren't enough and they are giving out in the course of time. Power plants, which are builded by using hydraulic energy are expensive, their building time is long and they respond to demand of consumer for short period. Renewable energy sources: sun rises, wind energy etc. are natural energy sources but using to them is very hard. Because using of natural energy sources is very expensive to need high technology and their production changes with seasons, the time period of day and night. In order not to be found any kind of energy to solve the problems about energy by recent technology which has important high efficiency has to be obtained by the primer energy resources in use. In classical systems, electrical energy required is got from power plants and heat energy is from steam boiler. The cogeneration, which is defined as, combined production of heat and power is a combined production of mechanical power and heat energy in the same central over a single energy source.

II. COGENERATION SYSTEMS AND THEIR OPERATING

In industrial establishments both electrical energy and steam which is at different levels are used. In an industrial establishment, which include a conventional power plant that produce electrical energy, the need of heating energy is obtained from boiler and auxiliary devices. So fuel is expended for heating too. In these systems, steam is accepted as waste. Steam at different pressure levels that is accepted as waste in conventional systems, is used in the some parts of industrial systems, which include cogeneration power plant. In this way efficiency is increased and cost of addition fuel and rigging are disappeared.

Since the first and second world oil shock occurred, the cogeneration plants are being continuously constructed in many countries. A cogeneration system usually supplies the thermal energy source simultaneously. Therefore it is called as a total energy system. It typically shows a higher efficiency than thermal power plant. Because it can be constructed in urban areas, the waste heat can be used as process heat. Therefore, it has been recently used as distributed electric energy source by electric utilities as well as thermal source.

Besides this, classical systems could be effected by potential energy interruption. Especially for the manufacturing industry, an un interrupted supply of power, process steam and cooling is of existential importance. Even short-term outages can cause major economic losses for companies in the chemicals, paper, metallurgical, food and brewing industries. However, operating combined heat and power production systems computed with grids, ratio effected by power interruption is reduced minimum.

For an industrial combined heat and power plant running against heat load the excess power demand can usually be fulfilled by purchasing electricity from the grid. The plant will be sized and designed for the "heat dump". This makes the diesel/gas engine a very profitable prime mover due to the high ratio of electrical output/heat output. For the same "heat dump" size electricity is got much more from a gas or diesel engine compared to the other available power generating prime movers.

When a Combined Heat and Power plant is used for hot water generation, the total thermal efficiency is generally very high. If the return water temperature is quite low, it is possible to utilise the waste heat of the exhaust gases, that of the engine's high-temperature cooling circuit and also that of the lubrication oil cooling circuit. These heat sources, in connection with an exhaust gas economiser, can produce very high thermal efficiencies, reaching up to 85% with fuel oil and 90% with gas applications.

There are cases when the heat demand of the heat network occasionally is higher than the supply from the Combined Heat and Power unit. In other cases the needed heat to power ratio is higher than that of the engine. In such cases it is always possible to

install an exhaust gas boiler with supplementary firing to each the heat to power demand, but a more simple solution is an auxiliary boiler connected to the same water system.

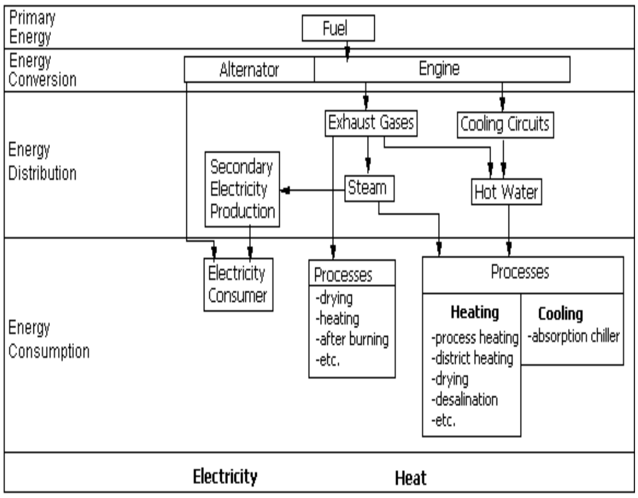
The exhaust gas of a reciprocating engine contains less energy than that of a gas turbine. The temperature of exhaust gas coming from reciprocating engines ranges from 330°C to 420°C, compared to gas turbine exhaust temperature above 500°C. Another notable factor is the oxygen content, which is in the region of 10% to 12%, when gas turbines show higher values, around 15%. From these features alone one can draw the conclusion, that gas turbines can compensate their lower electric efficiency by a higher steam production in a combined cycle. The cooling water of the gas engine is an easily accessible source of heat for different purposes and the cooling circuits can be combined in different ways to optimise the output, in accordance with the available heat consuming systems, like hot water systems, district cooling/heating or other processes.

A typical Combined Heat and Power plant generating 7 to 8 bar steam has a total efficiency of 65-68% of the input fuel energy. The efficiency depends on how much of the engine cooling water energy can be recovered. When generating electricity and steam, only a small part of the cooling water heat can be recovered, but the excess heat in the cooling water can of course be used for separate hot water generation [3].

The steam generation system with an auxiliary oil or gas fired boiler in parallel with the exhaust gas boiler is very flexible. The steam pressure can easily be controlled by the output of the oil or gas fired boiler while the exhaust gas boilers run 100% capacity. The auxiliary boilers come in standardised sizes with all needed equipment. This makes them relatively simple, cheap and easy to install.

Combined cycle plants use both the gas turbine cycle (Brayton Cycle) and the steam turbine cycle (Rankine Cycle). A basic combined cycle cogeneration configuration consists of one or more gas turbines used in conjunction with a dedicated Heat Recovery Steam Generator(HRSG) connected in their exhaust path. The steam produced in the HRSG (at one or more pressure levels) is fed to a steam turbine driving an electric generator. The steam extraction from the steam turbine, after suitable conditioning is normally used to apply an external user.

Table1. Combined Heat and Power with A Gas Engine as Prime Mover



III. CREATING MODEL AND SIMULATION OF EXAMINING PLANT

In this thesis, operating of combined heat and power generating systems which produce electricity and heat that is developed for transferring efficient energy at the same system are discussed. The configuration of the real cogeneration plant which is run under the loads consists of a gas turbine used in conjunction with a Heat Recovery Steam Generator (HRSG) connected to the exhaust path. This simple cycle system is used when the electrical demand and the thermal(steam) demand at the installation are relatively constant and are closely matched to output of the system. Generated electricity control is examined by acquiring mathematical model of a selected system.

On the concerning work, one month data sets reporting every one-hour period of industrial plant's cogeneration plant are used. Representative time periods can be: selected days, weeks or even the whole period of a month or a year. During this period data are taken. The more frequent data sets are recorded, the more accurate the final result will be. This survey delivers detailed data for the electrical power demand and any thermal energy demand in terms of process steam flow rates, pressure and temperature. For gas turbine based plants record of the ambient temperature are also of importance. Functional model of the plant is created using the data sets. The volume of outlet power as electricity, exhaust gas temperature, steam pressure and steam quantity can be observed by this model.

On the circumstances on real systems which is not practical to experiment (in engineering), physical models are used. There are some mathematical models represents those physical models. Creating mathematical model of the combined Heat – Power systems, can control the system. Using created mathematical model; the system will be gained to be checked successfully. At such plants, using control systems could accelerate efficiency.

Several models of Combined Heat and Power Plants have been completed as yet [2],[1]. These kinds of models are usually based on experimental studies.

Based on the functional model(Figure2), the new model(Figure3) on S-domain of the system is obtained. After the system is expressed on S-domain, the control of electricity generation as an outlet value is checked. One of the most important effects to efficiency is ambience temperature. If it is desired to obtain desirable electrical power with regard to the system capacity without decreasing the efficiency rate from HRSG, the system must be controlled throughoutly. To manage this, the desired temperature to obtain demanded power is determined. Then, air in the certain temperature should be touched the surface of the turbine. In this study, how to create such systems is shown. In the conclusion, how to reach the desired power with various control devices and so does the period is shown. Thus, desirable efficiency from the system becomes obtainable. As generating electricity the PID control system is used. Thanks to the model, the control of generating electricity is managed.

In this study, ambience temperature is distorting effect. This effect is not composed properly by the control system used. Therefore, two stepped control technique is used(Figure 4). Two stepped control technique is usually used in uncompensated distorting input effects through the single-circle control. Basically, two stepped control has some effects, which enhance the system's band-width and decrease distorter gains in the circle. The control's effect on the system is shown in Figure 6.

Table 2. A Part of Using Data Sets

A.T.	O.T.C.	O.P.C.	I.T.E.G.	E.P.	I.P.C.	O.T.E.G.	F.Q.	S.P.
5	676	10,8	446	4786	1	285	0,452	7,5
6	677	10,8	446	4756	1,01	287	0,454	7,3
7	675	10,8	446	4761	1	284	0,454	6,8
8	677	10,8	446	4732	1	282	0,455	7,1
9	676	10,7	447	4695	1,013	285	0,457	6,9
10	675	10,7	447	4658	1,011	283	0,46	7,4
11	676	10,6	447	4635	1	284	0,46	6,9
11	678	10,7	447	4648	1	284	0,46	7
11	676	10,6	448	4615	1	285	0,46	6,6
11	676	10,7	448	4629	1	285	0,456	7,5
9	676	10,8	447	4700	1,013	285	0,455	7,3
8	677	10,8	447	4733	1,013	287	0,454	6,6
8	676	10,8	447	4715	1	285	0,454	6,8
7	675	10,8	447	4743	1	283	0,454	7,4
7	676	10,8	446	4749	1	286	0,454	7,2
6	676	10,8	447	4744	1	285	0,45	7,7
6	677	10,7	446	4751	1	284	0,45	7,3
6	675	10,9	446	4753	1	285	0,45	7,3
6	676	10,8	446	4770	1	285	0,45	6,9
6	677	10,8	446	4803	1,011	286	0,45	7,3
6	676	10,9	446	4802	1	284	0,448	7,3
6	676	10,8	446	4803	1,013	284	0,45	6,9
6	676	11	446	4809	1	284	0,449	7,5
6	676	10,9	447	4784	1	284	0,45	7,7

A.T:Ambience Temperature(°C) ,O.T.C.:Output Temperature of Compressor (°C), O.P.C.: Output Preasure of Compressor(bar), I.T.E.G.:Input Temperature of Exhaust Gas(°C), O.T.E.G.:Output Temperature of Exhaust Gas(°C), E.P.: Electric Production(kw), I.P.C.:: Input Preasure of Compressor(bar), F.Q.: Fuel Quantity(kg/s), S.P.: Steam Preasure(bar)

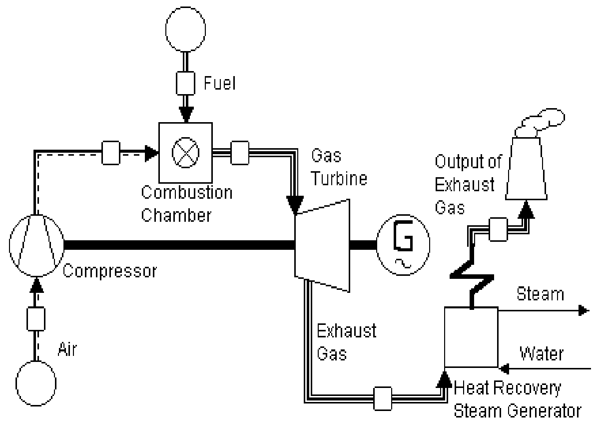
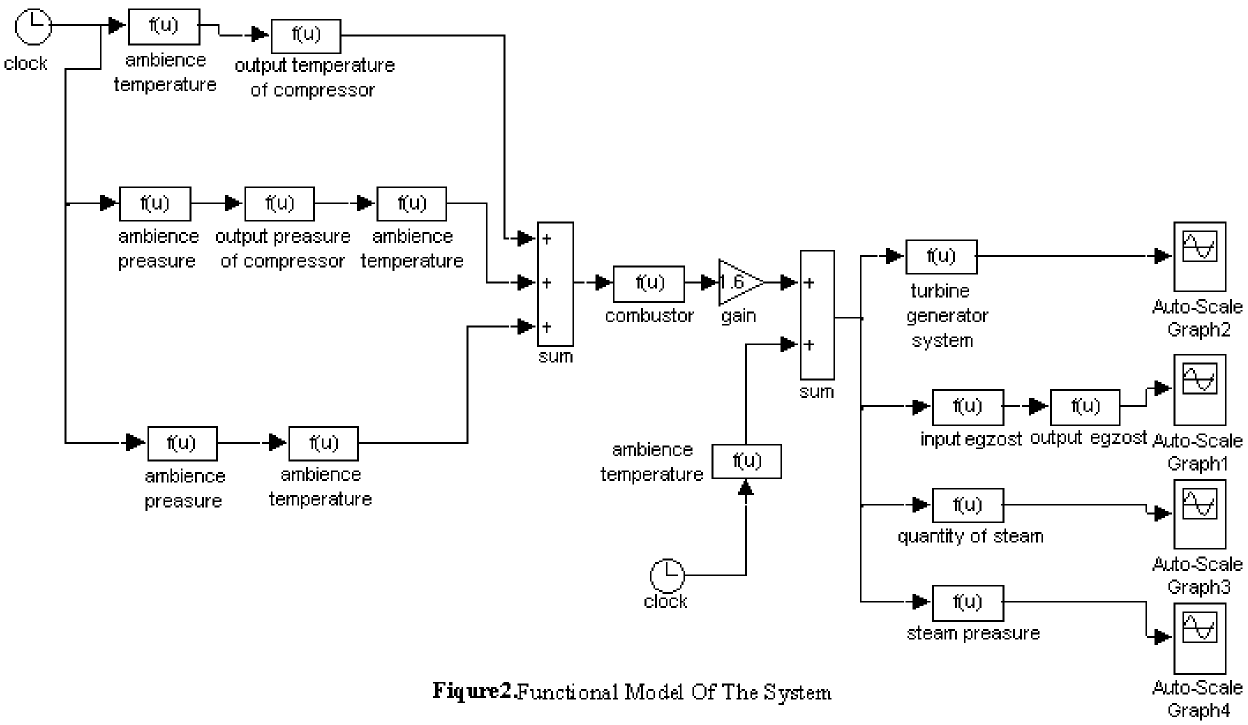
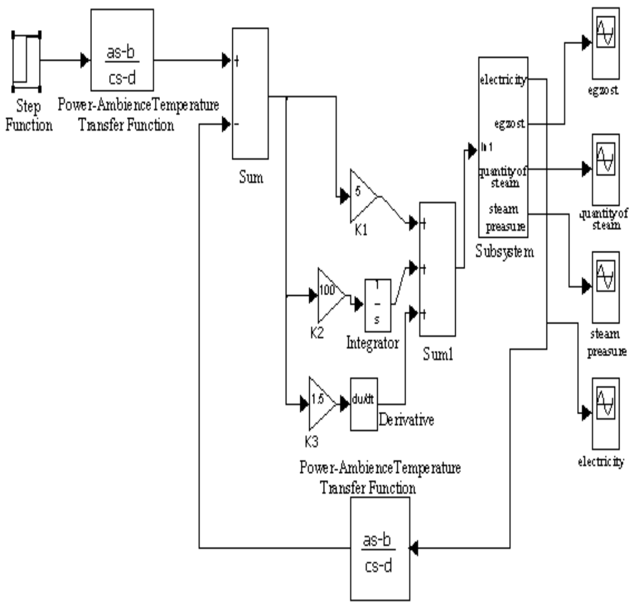


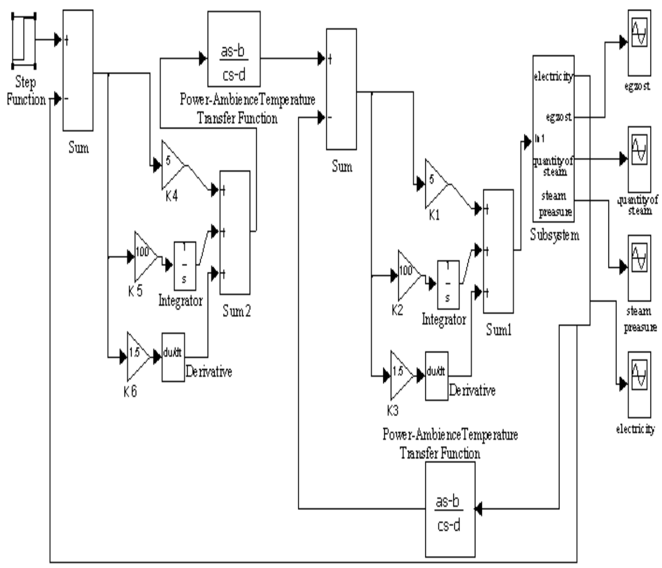
Figure1. Basic Model of the Selected System



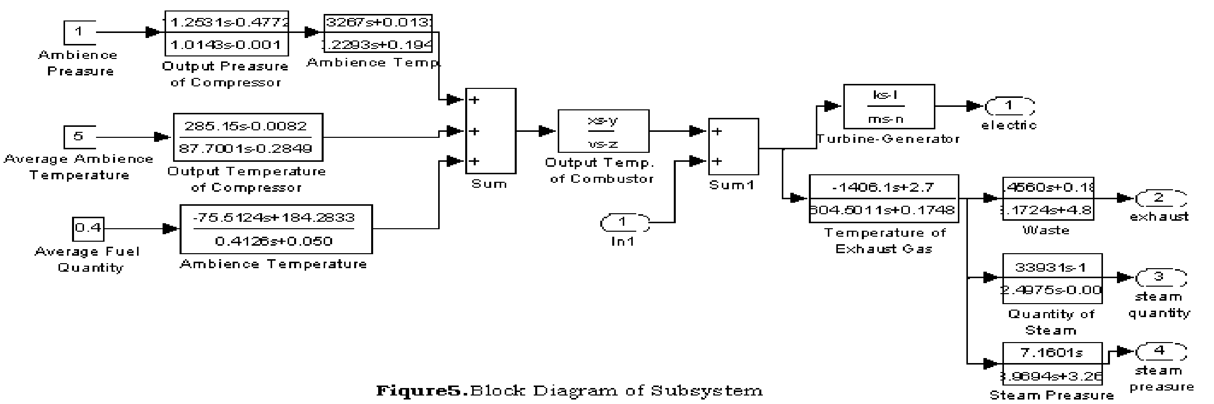
Fiqure2. Functional Model Of The System



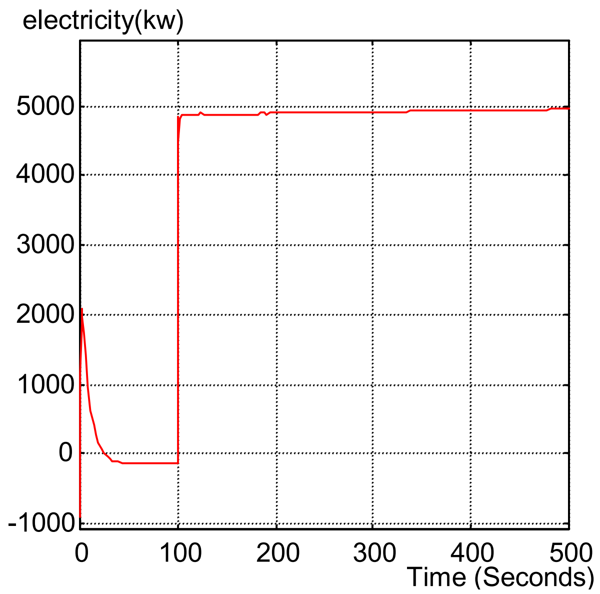
Fiqure3. Block Diagram of The System at S-Domain



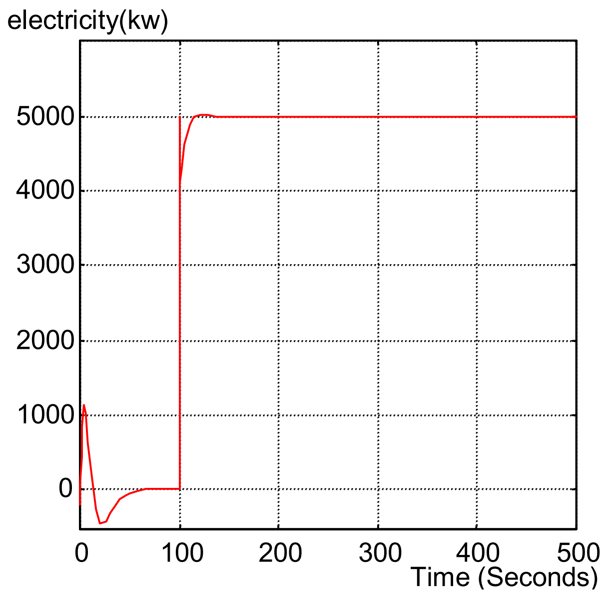
Fiqure4. Block Diagram of The System at S-Domain With Two Stepped Controller



Fiqure5. Block Diagram of Subsystem



Fiqure 6. Simulation Result Of The System



Fiqure 6. Simulation Result Of The System (Two Steped Control)

IV.CONCLUSION

In general cogeneration can be viable solution for the energy service of industries. Modern cogeneration plants with gas turbine offer high efficiencies at competitive power and heat costs. In addition it is an environmentally bening technology. Experience and capacities of an energy utility, e.g. in marketing surplus electiricity,can help to optimize the adaptation of the energy plant and its operation to the needs of the industrial energy consumer.

It is used advantages to have control by creating mathematical model of generation systems in Combined Heat and Power Plants. For operating of CHP efficiently, it's useful that using control methods. At this study generated electricity control is examined by acquiring mathematical model of selected system.

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