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ANALYSIS AND PROJECTION OF TRIGENERATION HEAT, ELETRIC AND COOLING LOADS

TRIĢENERĀCIJAS SILTUMA, ELEKTRISKĀS UN AUKSTUMA SLODŽU PROGNOZE UN ANALĪZE

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Introduction

Trigeneration is the simultaneous production of heat, power and cooling, where a fraction of the shaft work or residual (waste) heat is used for driven a refrigeration systems (technologies) – absorption, adsorption or ejectors cycles. It is like an extended cogeneration, but is becoming economically viable thanks to the commercial spread of absorption cooling systems. In fact, a well-projected trigeneration plant can achieve better results than cogenerative one. The results of investigations show that trigeneration has advantages over single electricity generation and cogeneration: the total energy efficiency is higher, the emissions of CO_2 and the other waste gases are lower and it has more useful energy outputs. This kind of energy production has both economic and environmental merits. One of the ways to research and investigate trigeneration is (users) load analyses using linear programming or mathematical models.

Area of focus

The main advantage of trigeneration is that: almost usually cooling demand in residential areas is increasing than heat consumption is decreasing, e.g. typical it is in summers. The cooling load can equalize overall consumer's heat load in the summer period. Cogeneration plant is operating according to heat load and than in proportion generates electricity, and in case when there is a high heat load (generally in winter), the output of electricity overachieve demand and electricity can be supplied to the grid and sell to the operator. It is environmentally friendly and economically viable if a cogeneration plant operation is based on heat load.

Simplified trigeneration consists of three subsystems: power plant, heat station and cooling station. The performance of the whole system depends on how the subsystems are joined to one another. The fig. 1 represents trigeneration energy balance.

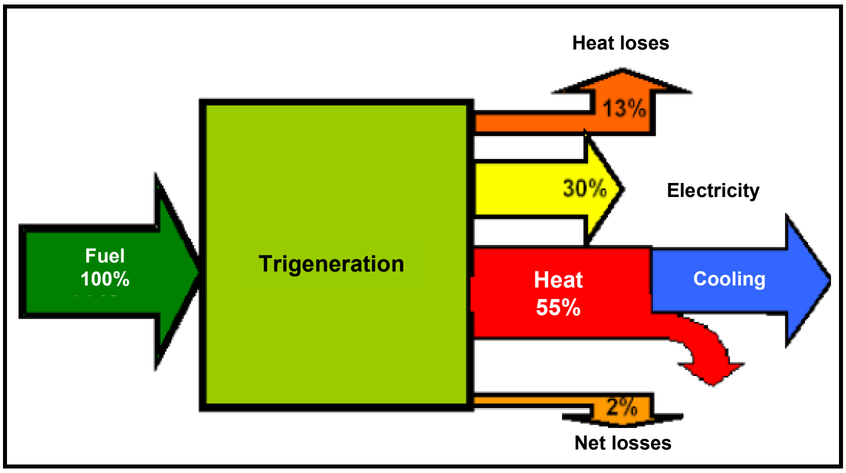

Figure 1. Trigeneration energy balance

The economic viability of a trigenerational (similar in cogeneration) system depends primarily on matching the thermal and electrical loads of a particular site with the heat and power outputs of the system, so that the trigeneration plant runs for a maximum number of hours per year. The availability of net metering and the possibility of exporting excess electricity are also important. In many applications however, it is not possible to utilize all the available heat at certain periods of the year as the demand for space heating is greatly reduced [1].

Heat, cooling and power load profiles are independent of each other [2]. Energy demand depends on a great number of factors: the type of users and customers, sites and climatic conditions, plants supplying energetic outputs and management criteria. The final energy consumption can be summarized as follows: space heating, space conditioning and ventilating in summer, cooling, hot water, lighting or various electrical equipment. Two management philosophies are compared:

- The thermal demand management, that is the most widespread management criterion and is based on working the engine strictly following thermal demand;
- The primary energy saving management, to achieve maximum energy savings during the plant life cycle.

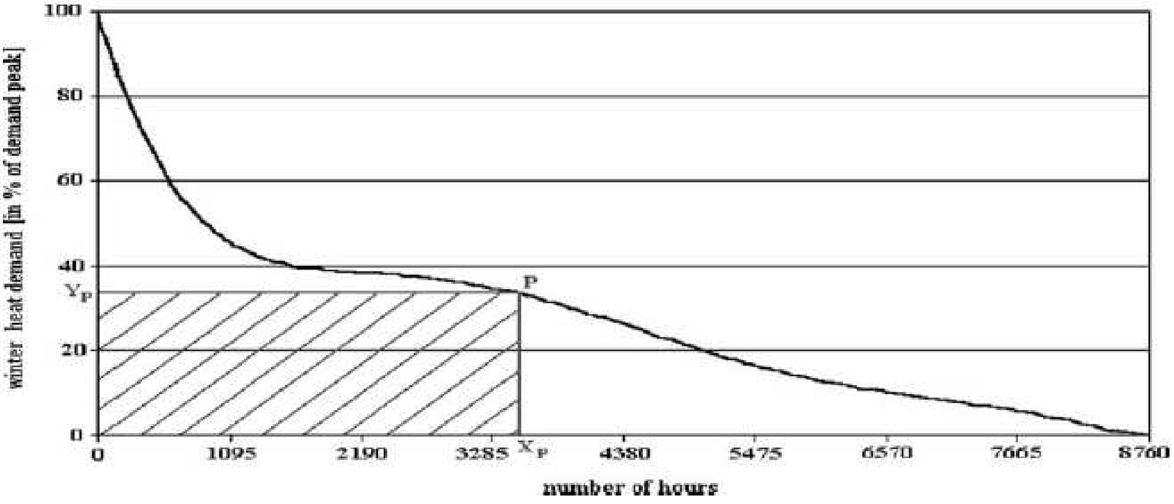

Figure 1. Average cumulative curve of winter heat consumptions, parameterized to thermal demand peak [3]

Interpolated the parameterized curves and derived an average cumulative curve for heat demand represented in Fig. 1. One of the most common choice methods is based on the cumulative curve, and in particular it is finalized to choose the prime mover size Y_P, to maximize the hatched area X_PY_P. Such area represents, in fact, the heat amount annually supplied at full load; when this area is maximized, a good part of the annual heat consumption is provided by heat recoveries in the engine, while running at elevate load levels.

Then the purpose of any combined heat, power and cooling installations is to maximize yearly amount of “cogenerated” energy and this leads to choose an engine size as large as possible, until its rated heat output is required by final users for a large number of hours [3]. For that reason it is useful to make analysis and projection of expected loads and loads profiles.

A procedure for optimizing energy-management of a user is described, which, starting from hourly load diagrams, derived from the optimal design, allows the determination of the design and the running conditions of a trigeneration plant. Based on the hourly electrical, thermal and cooling load diagrams it is possible to developing the model to delineate the optimal operational strategy of a trigeneration plant which maximizes short-term economic returns over a calendar year and calculates the savings over a conventional plant configuration [4]. Load profiles of the different energy products are usually independent of each other, thus increasing the evaluation complexity [5]. There are a lot of mathematical programming techniques and linear programming models to determine operation strategy as a function of user demand.

The hourly energy load diagrams were therefore determined by taking into account the annual consumption, the energy absorption of each hospital service unit (technological services, heating, cooling and lighting services, etc.) and their hourly distribution, and assuming that the energy loads of each hospital service unit were constant year-round [4]. Cost-efficient operation of a trigeneration system can be planned using an optimization model based on hourly load forecasts. A long-term planning model decomposes into thousands of hourly models, which can be solved separately [6]. Programming model can solve the optimal sizing problem and optimal operational strategy, both daily and seasonal, of a trigeneration system to meet the necessary energy demand.

The optimal sizing of the two alternative plants, both in terms of the size of single components within each configuration, and in terms of the daily running of the plant as a function of a range of variables (e.g. load profiles, required temperature levels, operating temperature, time-variable step-rates for electricity purchase, tax deductions for methane, tax on electricity which is purchased and/or self-consumed, costs for emergency backup electricity provisions, and plant maintenance costs) [4].

References

1. J. Godefroy, R. Boukhanouf, S. Riffat, Design, testing and mathematical modeling of small-scale CHP and cooling system (small CHP-ejector trigeneration), Institute for Sustainable Energy Technologies, School of the Built Environment, University of Nottingham, University Park, Nottingham NG7 2RD, UK.

2. E. Cardona, A. Piacentino, Optimal design of CHCP plants in the civil sector by thermo economics, Department of Energetic and Environmental Researches, Faculty of Engineering, University of Palermo, Universita` di Palermo, Viale delle Scienze, 90128 Palermo, Italy.

3. E. Cardona, A. Piacentino, A methodology for sizing a trigeneration plant in mediterranean areas, Department of Energetic and Environmental Researches, Faculty of Engineering, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy.

4. P. Arcuri, G. Florio, P. Fragiacomo, A mixed integer programming model for optimal design of trigeneration in a hospital complex, Department of Mechanical Engineering-University of Calabria, Arcavacata di Rende, 87030 Cosenza, Italy.

5. E. Cardona, A. Piacentino, Optimal design of CHCP plants in the civil sector by thermoeconomics, Department of Energetic and Environmental Researches, Faculty of Engineering, University of Palermo, Viale delle Scienze, 90128 Palermo, Italy.

6. Aiying Rong, Risto Lahdelma, An efficient linear programming model and optimization algorithm for trigeneration, Department of Information Technology, University of Turku, Lemminka¨ isenkatu 14 A, FIN-20520 Turku, Finland.

Jaunzems D., Veidenbergs I. Triģenerācijas siltuma, elektriskās un aukstuma slodžu prognoze un analīze.
Rakstā ir detalizēti aplūkota triģenerācijas iekārtu vispārīga uzbūve un darbības principi, kā arī to priekšrocības un iespējas. Ir veikta slodžu analīze, interpolējot grafikus ar parametriem, izveidots atvasināta vidējā kopējā siltuma patēriņa grafiks. Ir izvērtētas īstermiņa un ilgtermiņa triģenerācijas iekārtas optimizācijas procedūras un stratēģija (dienas un sezonālā), kā arī identificētas to galvenās mērķfunkcijas un pamatelementi. Optimizācijas procedūras ir sasaistītas ar enerģētiskās saimniecības organizāciju un uzlabošanu. Saistībā ar optimizācijas procedūrām tika definēti galvenie enerģijas (enerģētiskās) bilances – elektroenerģijas, siltumenerģijas un dzesēšanas enerģijas bilances – ierobežojumi, kuri ietver arī siltuma, elektriskās un aukstuma slodzes, kā arī citi siltumtehniskie parametri. Pamatojoties uz šiem enerģijas (enerģētiskās) bilances ierobežojumiem un balstoties uz elektriskās, siltuma un aukstuma ik stundas slodžu diagrammām, sākta triģenerācijas iekārtas optimālu konstrukciju un uzbūvi aprakstoša matemātiska un programmējama modeļa izstrāde, lai attēlotu optimālo triģenerācijas darbības stratēģiju, kas palielina ekonomiskos ieguvumus un finansiālos ietaupījumus īstermiņa periodā un identificē arī citus saistītus un izmērāmus lielumus. Lai noteiktu sākuma investīciju un amortizācijas izdevumu ietekmi uz investīciju atdevi, pielietoti dažādi ekonomiskie indikatori.

Jaunzems D., Veidenbergs I., Analysis and projection of trigeneration heat, electric and cooling loads.
In the paper is implemented a general evaluation of trigeneration, including an analysis of different components and operation principles. The main advantages and facilities are identified. In loads analysis was interpolated the parameterized curves and derived an average cumulative curve for heat demand. Appraised a short-term (the solar year) and a long-term optimization procedures and strategy (both daily and seasonal), recognized their objective functions and basic elements. Optimization procedures are tieback with energy-management organizing and improvement. Responsibility to optimization procedures, define head energy balance constrains – electric balance, thermal balance and cooling balance constrains as well as other heat engineering parameters. On this bases energy balance constrains and based on the hourly electrical, thermal and cooling load diagrams was started developing of the mathematical model to delineate the optimal operational strategy and design of a trigeneration plant which maximizes short-term economic returns over a calendar year and calculates the savings over a conventional plant

configuration or other specifically measurement values. To determine the effects that initial investment costs and amortizations have on investment return, economic indicators were used.

Яунземс Д., Вейденбергс И., Анализ и прогноз тепловой, электрической нагрузки и холодоснабжения в режиме тригенераций.

В статье подробно рассмотрено общее строение тригенерационой установки и структурный процесс работы, а также её преимущества и возможности. Проделан анализ нагрузки, интерполированы графики с показателями, создан средний общий график расхода теплоты производной величины. Сделана оценка краткосрочных и долгосрочных оптимизирующих процедур и стратегии (дневной и сезонный) тригенерационой установки, равномерно идентифицированы главные целевые функций и основные элементы. Оптимизирующие процедуры увязаны с организацией и усовершенствованием энергохозяйства. В связи с оптимизирующими процедурами, определены главные ограничения энергетического баланса - тепловой энергий, электроэнергии и энергии холодоснабжение, равномерно с другими теплотехническими параметрами. Исходя из этих ограничений энергетического баланса и основываясь на диаграммах ежечасной нагрузки тепла, электроэнергии и холодоснабжения, начата разработка математической модели, чтобы изобразить оптимальную стратегию работы тригенерации, что увеличит экономические показатели и сбережения финансовых ресурсов в краткосрочным периоде времени и позволит идентифицировать другие сопричастные величины. Чтобы определить влияние первоначальных инвестиций и затраты на амортизацию на эффективность инвестиции, применены разные экономические индикаторы.