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Challenges of Incorporating Co-Generation Technology in Nigeria Power System

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***Abstract* – Cogeneration or Combined heat and Power (CHP) is the simultaneous production of electricity and heat using a single fuel such as natural gas, coal, waste gas, biomass liquid fuels and renewable, with a view to practical application of both products.**

This paper examines the challenges of incorporating cogeneration technology in Nigeria Power Network. These ranges from technology, government policies to skilled man power. However, recommendations were made in tackling some of these challenges for the overall improvement of power generation in Nigeria.

***Keywords* – Cogeneration, Combined Heat and Power (CHP), Nigeria Power Network, Nigeria Power System.**

I. Introduction

Cogeneration is not a new concept, since it first appeared in late 1880s in Europe and in the U.S.A. during the early parts of the 20th century, when most industrial plants generated their own electricity using coal-fired boilers, steam-turbine generators and when steam was the primary source of energy in industry, electricity was just surfacing as a product for both power and lighting. Many of the plants used the exhaust steam for industrial processes. When central electric power plants and reliable utility grids were constructed and the costs of electricity decreased, many industrial plants began purchasing electricity and stopped producing their own. Other factors that contributed to the decline of industrial cogeneration were the increasing regulation of electric generation, low energy costs which represent a small percentage of industrial costs, advances in technology such as packaged boilers, availability of liquid or gaseous fuels at low prices, and tightening environmental restrictions. [Hsu, 1999] The trend in cogeneration started being inverted after the first dramatic rise of fuel costs in 1973. Systems that are efficient and can utilize alternative fuels have become more important in the face of price rises and uncertainty of fuel supplies. In addition to decreased fuel consumption, cogeneration results in a decrease of pollutant emissions. For these reasons, governments in Europe, U.S.A. South East Asia and Japan are taking an active role in the increased use of cogeneration. In India, the policy changes resulting from modernized electricity regulatory rules have induced 710 MW of new local power generation projects in Sugar Industry. Other core sector industries are also already moving towards complete self generation of heat and electricity in a combined process. [Irwin, 2001]

The need for electric power may be analyzed by a fairly intensive and deep study, which invariably requires life cycle analysis of the society in terms of energy use and conservation, industrial and household development, population and industry distribution, export and import of electricity, etc. in contemporary power applications, cogeneration or combined heat and power (CHP) provides an interesting technology for maximizing energy utilization.

Cogeneration often replaces the traditional methods of acquiring energy, such as purchasing electricity from the power grid and separately burning natural gas or oil in a furnace to produce heat or steam. While the traditional method of purchasing electric energy from a utility is convenient, it is very inefficient and wastes almost 75 percent of the energy in the original fuel due to production and transportation losses. [Alexander et.al, 2006]

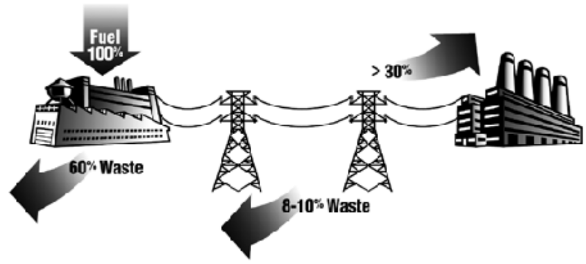

Fig.1. Today's "grid" system of central power plants and transmission lines wastes much of the energy in the original fuel. [Hsu, 1999]

On-site cogeneration systems convert 70 percent to 90 percent of the energy in the fuel that is burned into useful electricity or heat. Depending on the application, the integration of power and heating/cooling production into one on-site cogeneration system can often produce savings of up to 35 percent on total energy expenditures. [Joel, 2008]

Cogeneration is environmentally-friendly, economically sensible way to produce power, simultaneously saving significant amounts of money as well as reducing greenhouse gas emissions. It is a significant measure to enhance industrial competitiveness. It is one of the most efficient energy conversion processes with large cost saving potential which boosts competitiveness of the industries.

The power generated from cogeneration projects could be used for meeting the captive requirements and the surplus power could be exported to the grid. With the rising energy cost and unreliable grid power, there is good potential for industries to opt for co-generation, as a cost reduction measure. It is also noted that some factors which make installation of cogeneration attractive include significant cost savings relative to the separate supply of electricity and heat. [Na Raghu, 2010, Alexander et al, 2006 and Hussain, 2007].

The efficiency of energy conversion increases to over 80% as compared to an average of 30–35%for conventional fossil fuel fired electricity generation systems. This increase in energy efficiency can result in lower costs and reduction in greenhouse gas emissions when compared to the conventional methods of generating heat and electricity separately. [Onovwiona et.al, 2004]

II. Objective of Study

Hydro and thermal power plants are major sources of electricity supply in Nigeria and this conventional method of power generation and supply to the customer is wasteful in the sense that only about a third of the primary energy fed into the power plant is actually made available to the user in the form of electricity. In conventional power plant, efficiency is only 33%. The major loss in the conversion process is the heat rejected to surrounding water or air due to inherent constraints of the different thermodynamic cycles employed in power generation. Also further losses of around 10-15% are associated with transmission and distribution of electricity in the electrical grid. [Joel, 2008, Suresh, 2007]

The idea is to suggest ways in which power output in the Nigerian Power Network can be improved and with cogeneration the present demand for electricity can be met. Cogeneration also bridges the gap between supply and ever increasing demand of electrical energy and becoming self reliant in terms of captive electrical power rather than depending on national grid. This paper also talks about the cogeneration technology, applications and potential benefits the Nigerian Power Network hopes to benefit if implemented, e.g. reducing the loads on the grids.

III. Cogeneration versus Conventional Power Generation

Conventional power generation is based on burning a fuel to produce steam. It is the pressure of the steam, which actually turns the turbines and generates power, in an inherently inefficient process; no more than one third of the energy of the original fuel can be converted to the steam pressure, which generates electricity. Cogeneration, in contrast, makes use of the excess heat, usually in the form of relatively low-temperature steam exhausted from the power generation turbines. Such steam is suitable for a wide range of heating applications, and effectively displaces the combustion of carbon-based fuels, with all their environmental implications. [Elliot, 1999, Major, 1995]

Some benefits of cogeneration include; very low transmission and distribution losses, less burden on government power generation, less environmental pollution, security of supply and reliable power.

Although less of the fuel energy may be converted to electricity, producing both electricity and useable thermal energy can lead to higher overall efficiencies. For example, using natural gas to produce steam in a conventional boiler is a missed opportunity. Natural gas is a high quality fuel that can be used to produce electricity while waste heat from this process can be used to produce steam.

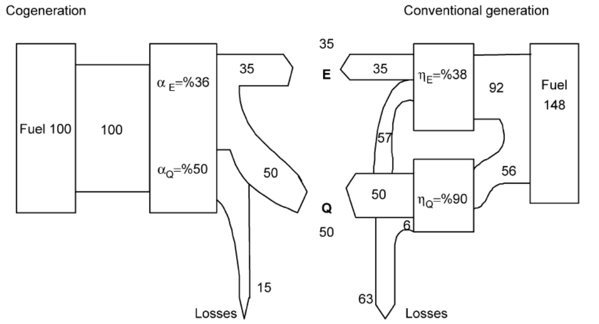

Fig.2. Cogeneration system versus Conventional energy system. [Onovwiona et al]

Where α_E, part of energy transformed into electricity in a cogeneration unit, α_Q, part of the energy transformed into usable in a cogeneration unit, η_E, electrical yield of an electrical power plant (production of electricity only), η_Q, yield of a boiler (production of heat only), E, electricity demand, Q, heat demand.

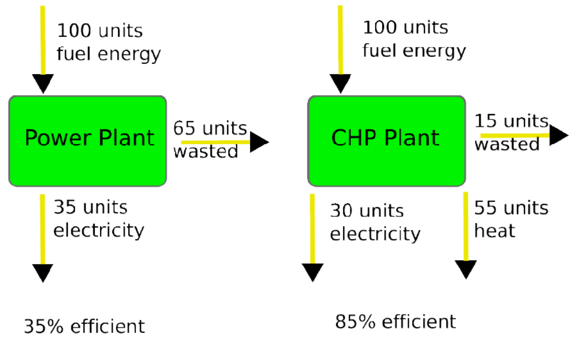

Fig.3. Efficiency of Cogeneration and Conventional Power Plant [Cogen Europe, www.cogen.org]

IV. Cogeneration Technology

Cogeneration types include steam turbine cogeneration, gas turbine cogeneration, combined cycle cogeneration (combine steam & gas cycle cogeneration), gas engine cogeneration and steam engine cogeneration. [Harsh and Onovwiona, 1999]

Cogeneration system consists of a prime mover turning an alternator to produce electricity and a waste heat recovery system to capture heat from the exhaust and engine cooling waste jacket. The prime mover could be a lean-burn natural gas reciprocating engine, diesel reciprocating engine and gas turbine, each prime mover is the heart of cogeneration that has the characteristics that make one or another better suited to a particular application. Systems based on reciprocating engines offer the greatest electrical output per Btu of input energy and highest overall efficiency. [Joel, 2008]

(a) Steam turbine cogeneration

Two types of steam turbine most widely used are the back pressure and extraction-condensing types. The choice between back pressure turbine and extraction-condensing turbine depends mainly on the quantities of power and heat, quality of heat and economic factors. The extraction points of steam from the turbine could be more than one, depending on the temperature levels of heat required by the processes. The specific advantage of using steam turbines in comparison with the other prime movers is option for using a wide variety of conventional fuels as well as alternative fuels such as natural gas, fuel oil and biomass.

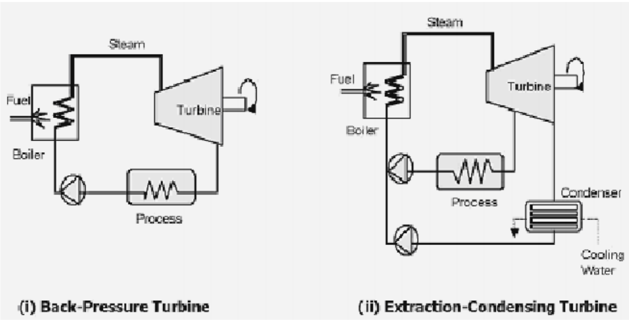

Fig.4. Schematic diagrams of steam turbine co-generation systems. [European Commission, 2001]

(b) Gas turbine cogeneration

Gas turbine co-generation system can produce all or part of the energy requirement of the site, and the energy released at high temperature in the exhaust stack can be recovered for various heating and cooling applications. Though natural gas is most commonly used, other fuels such as light fuel oil or diesel can also be employed. The typical range of gas turbines varies from a fraction of a MW to 100 MW.

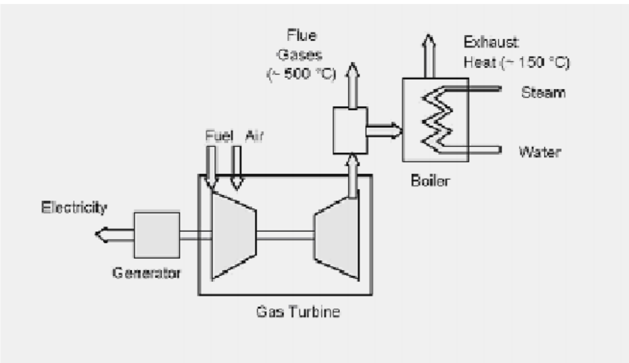

Fig.5. Schematic diagrams of gas turbine co-generation systems. [European Commission, 2001]

(c) Reciprocating engine co-generation systems

It is also known as internal combustion engines; these co-generation systems have high power generation efficiencies in comparison with other prime movers. There are two sources of heat recovery: 1) From exhaust gases at high temperature and 2) From engine jacket cooling water system at low temperature. As heat recovery can be quite efficient for smaller systems, these systems are more popular with smaller energy consuming facilities, particularly those having a greater need for electricity than thermal energy and where the quality of heat required is not high.

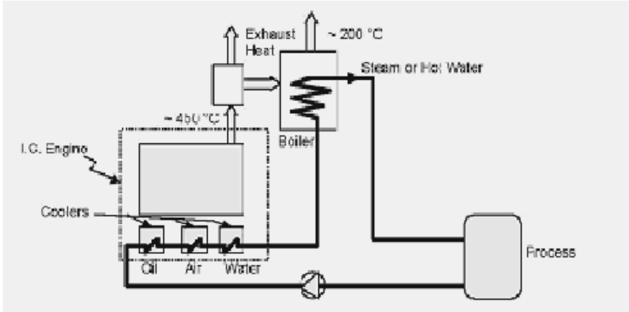

Fig.6.Schematic diagrams of reciprocating engine co-generation systems. [European Commission, 2001]

V. World wide Applications of Cogeneration

Cogeneration is the sequential use of fuel energy to produce more than one finished energy product, such as steam, electricity, cooling, thermal drying, heating, etc, this sequential energy production yields fuel savings relative to separate energy production facilities, or It is the simultaneous production of power and heat, with a view to fully utilize the fuel source.

Listed below are some of cogeneration plants in different parts of the world.

A coal thermal power plant, Kobe Steel's Shinko Kobe Power Station, Japan, consists of 1,400MW (700MW x 2 generators), produces electricity and steam. [Kida et al, 2003]

A chemical industry engaged in manufacture of agrochemicals in India, located in Gujarat is having an approximate maximum demand of electricity up to 1.35 MW, Steam requirement up to 2.5 TPH and Chilled water @ 5 deg C up to 90 TR.

Jurys hotel and towers, located in ballsbridge, Dublin, consisting of 2 adjoining hotel blocks and comprising of 300 bedrooms. Electrical power output of 304KW, heat output 0f 445KW and fuel input of 9990KW.

Buchanan flooring, located in Aliceville, Alabama, U.S.A. a plant for the production of hardwood flooring (strip flooring), steam pressure, 19 bars and electricity output 90KW.

Lutherstadt Wittenberg, a power plant, located in Germany, electrical output 6.3KW, thermal output, 7948KW and primary fuel is natural gas.

District of cham (Switzerland), a total energy system, plants consists of a central heating plant, 543KW otto gas engine, 187KW of electricity generated, a water to water heat pump with 243KW thermal output

Hybrid cogeneration plant in Thailand, 514MW electricity, 200tph steam and 150m³/h demineralised water and a host of others. [European Commission, 2001]

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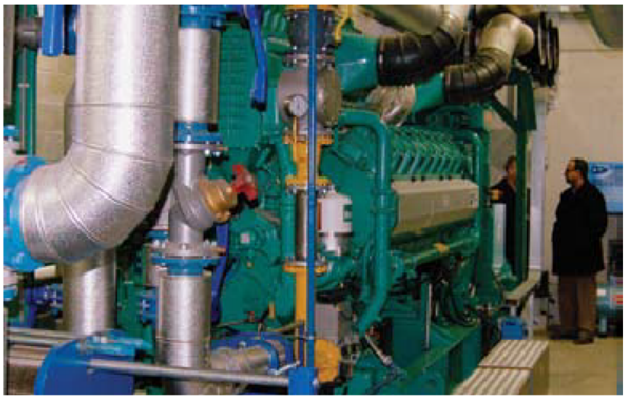

Fig.7. A 1.5 MW lean-burn gas generator set provides heat and power as well as CO2 to accelerate the growth of tomatoes at a large greenhouse in Belgium.

Fig.8. A 5.2 MW 60 gas turbines provide cogeneration at a medical center on a united states military base in San Antonio, Texas, U.S.A

Fig.9. A 3.5 MW Centaur 40 generator set provides electrical power and cogeneration for this petrochemical plant in merak, Indonesia. [Solar Turbines]

VI. Nigeria Power System

Nigeria, like most other developing countries, is grappling with the task of providing sufficient amounts of electricity to meet its needs and fuel its development. Adequate power supply is an unavoidable prerequisite to any nation's development, and electricity generation, transmission and distribution are capital-intensive activities requiring huge resources of both funds and capacity.

The government has, to this purpose, committed to the construction of more electricity generation plants. While this is a good idea, experience has shown that the power problem in Nigeria is much more than that of generated capacity.

The federal Government has grappled with the problem of power generation and distribution for years and has pumped not less than $4.06 billion into the sector without any significant result. [Popopla et al, 2008].

The Nigeria Power System; generating plants do not generate electricity to their capacities, some of the power stations generate less than 45% of their installed capacities. Total installed capacity of the generating plants is 7,876MW, available is less than 4,000MW, the maximum load ever achieved was little above 4000 MW. Most generating stations are old and require complete overhaul, By December, 2011 the average; generating capacity was about 2800 MW daily owning to corruption, political, grossly inadequate funding and mismanagement reasons. Currently, most of the generating units have broken down due to limited available resources to carry out the needed level of maintenance. Hence, the electricity net-work has been characterized by constant system collapses as a result of low generating capacity by the few generating stations presently in service. [Sunday, 2001 and Oshevire, 2012]

The transmission system comprises 5,523.8km of 330kV, 6,801.49km of 132kV and 32no. 330/132kV substations, it doesn't cover every part of the country, has the capacity to transmit a maximum of 4,000MW, technically weak, regular vandalization of the lines. Transformers deployed are overloaded in most service areas, weak distribution lines and inadequate spare parts for maintenance.

Incessant interruption of gas supply as a result of unrest in host communities, lack of diversity on energy mix in form of solar, coal and wind, lack of spare parts, policies on technical and maintenance issues, lack of sincerity in our power reform program, wrong selection of who manages the power sector, lack of professional project management plan and needed assessment to determine what exactly is needed before fund is committed, aged facilities limit power generation capacity in Nigeria. [Aribisala, Ayodele, 2008].

Repositioning of the power sector is a key stimulus to the rapid industrialization of all key sectors of the economy like manufacturing, telecommunications etc.

The International Energy Institute's comparative analysis of the per capita consumption of electricity worldwide (Table 1), underscores the stark reality of Nigeria's power sector. The comparative analysis shows the poor state of Nigeria's power sector, compared with some of the countries that began as newly independent countries in the 1960s. The challenge now is how reliable power supply can become accessible to majority of Nigerians at an affordable price.

Table 1: Comparative analysis of the per capita consumption of electricity, worldwide. [Sunday, 2011]

S.No.	Country	Population (Million)	Power Generation (MW)	Per Capita Consumption (KW)
1	USA	250.0	813,000	3.2
2	CUBA	10.54	4000	0.38
3	UK	57.5	76,000	1.33
4	UKRAINE	49.0	54,000	1.33
5	IRAQ	23.6	10,000	0.42
6	SOUTH KOREA	47.0	52,000	1.09
7	EGYPT	67.9	18,000	0.265
8	TURKEY	72.0	12,000	0.16
9	SOUTH AFRICA	44.3	45,000	1.015
10	NIGERIA	140.0	4000	0.03

Table 2: Power Stations and Capacity as at January 2010 [National control Center, Oshogbo]

Station	Type of Turbine	Energy Generated
		MW
KAINJI	HYDRO	266.46
JEBBA	HYDRO	307.08
SHIRORO	HYDRO	258.54
EGBIN	STEAM	910.04
TRANS AMADI	GAS	8.33
AES	GAS	196.17
SAPELE	STEAM	66.71
SAPELE NIPP	GAS	111.85
IBOM POWER	GAS	72.47
OKPAI	GAS	419.04
AFAM IV-V	GAS	89.06
AFAM VI	GAS	302.69
DELTA	GAS	94.79
GEREGU	GAS	252.54
OMOKU	GAS	16.04
OMOTOSHO	GAS	100.29
OLORUNSOGO PHASE I	GAS	5.35
OLORUNSOGO PHASE II	GAS	---
TOTAL		**3477.45**

VII. Challenges of Incorporating Cogeneration Technology in Nigeria Power System

In Nigeria, Cogeneration could be used in industries (wood & agro industries, food processing, pharmaceutical, pulp and paper, oil refinery, textile industry, steel industry, cement industry, glass industry, ceramic industry etc.) and in residential/ commercial / institutional (hospitals, schools & universities, hotels, houses & apartments, stores, supermarkets, office buildings etc). Incorporating cogeneration in Nigeria power system will reduce electricity deficiency, cost, yield fuel savings relative to the present separate energy production facilities and fully utilize the fuel source. Some of the challenges of incorporating cogeneration in Nigeria power system are: technology, government policies, finance and skilled manpower.

Technology: Technological requirement in cogeneration include that of turbine or reciprocating engine. Turbines are commonly used at the large end of the scale and reciprocating engines at the smaller end of the scale.

The system usually consists of a reciprocating engine connected to an electrical generator, with the engine operating at a rotational speed set by the generator design and the electrical frequency of the power system. Also required is an automatic control system which correlates gas consumption with hot water and electricity production. This fine tunes the operation when movement away from the set point is observed.

Finally billing for energy services provided by cogeneration, such as domestic hot water and electricity requires proper billing system expert in meter reading and billing is required. For now, this technology is not available and Nigeria completely depends on other countries.

Finance: The purchase of cogeneration plant and equipment could be hindered by finance as most industries are always daunted with financial problems and finance has been a constraint in developing economics. The high tariff on energy (electricity and gas) consumed by industries results in high overhead cost. The problems of finance are compounded by the general apathy being exhibited to production establishment by the Nigerian financial Institutions.

The procurement of loans from the financial houses is always a problem due to inadequate collaterals. This low level of financial resource limits the ability to explore cogeneration option in production.

The scarcity of spare parts is another major obstacle. The manufacturing industry in the country is still in its infancy state and so most of the parts of the equipment are imported. The problem of and process of foreign exchange and declining value of the Naira also adds to the problem.

Government Policies: Countries that have implemented cogeneration have regulator that is independent of established government bureaucracy and not a market participant. The regulator establishes the necessary policy guidelines, legal and regulatory framework to enable the smooth operation of a cogeneration plant.

In Nigeria, Nigeria Electricity Regulatory Commission (NERC) is the organization saddled with the task of setting rules and enforcing them to protect the lawful interest of stakeholders. It was established on October 31st 2005, under the electric power sector reform act 2005, as an independent regulator.

Their statutory function includes; evolve policies to attract investment locally and internally, develop and enhance indigenous capacity in electricity sector, issue license to utilities engaged in generation, transmission and distribution, monitor the efficient functioning of the licenses, fix transmission tariff and retail consumer tariff, arbitrate in dispute among licenses, ensure viability of the electricity industry, formulate transparent policies regarding subsides, protect consumers interests and promote efficient and environmentally sound policies, [Igbinovia and Odiase,2009] It has no policy on cogeneration.

Skilled Manpower: Human resources is one of the greatest assets in any establishment and since the staff are the people in the day to day running of the cogeneration equipment there should be appropriate and adequate on the job training program especially for operators and maintenance staff such as technicians, fitters, engineers etc. Cogeneration plant is sophisticated and highly automated, making use of electronic components. A lot of resources should be invested into the training of staff in terms of equipment, high level personnel and other essential resources for constantly maintaining plant facility longevity. Staff must continue to train and re-train as often as necessary to keep abreast with technological development and innovations. They must be encouraged to avail themselves of opportunities for such training; they must be actively involved in continuous professional development programmes of engineering bodies. Also staff should be trained on engineering management courses for efficient use and total utilization of the maintenance budget. Apart from training, efforts should be made to attract skilled man power.

VIII. Recommendations

Nigeria needs to acquire the cogeneration technology by sending engineers, technologists, technicians to those countries (Japan, U.S.A, Belgium etc) that have been using this cogeneration technology.

Presently Nigeria government doesn't have the policy cogeneration. Government should put necessary policy in place to enable industries, hospitals and other agencies to effectively operate cogeneration plant and derive the maximum benefit froe the technology.

Apart from training to get the necessary skill and man power to run the cogeneration plant, effort should be made to attract skilled man power.

IX. Conclusion

Nigeria is blessed with abundant resources as well as renewable energy resources. There is the urgent need to encourage the evolvement of cogeneration, i.e. energy mix that will emphasize the conservation of fossil fuels.

The adoption of cogeneration technologies in a decentralized energy manner, especially rural communities and in standalone applications will certainly lead to an improved power quality.

The major advantages of cogeneration energy technologies include the simplicity of the technologies, ease of maintenance as well as their enhanced environmental friendliness. Cogeneration systems produce both electricity and heat/cooling from the same fuel can offer savings of up to 35 percent for a wide range of facilities, while at the same time contributing to building sustainability and protecting the environment, Nigeria with a population of over 150 million people depending on less than 3000MW of electricity. It is hopeful that if these suggestions are taken seriously for cogeneration system, Nigeria in no doubt and in no time will join the advanced nations in singing the song of uninterrupted power supply.

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