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CONCENTRATED SOLAR POWER (CSP) PLANT PROPOSAL FOR BRAZIL

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PRESENTATION

This article is part of the research to obtain the title of Master in Renewable Energy with support of the division of postgraduate in Mechanical Engineering by the Taubate University, Brazil. The case study is the most interesting technology for generating high solar power capacity in Brazil if using solar concentrators.

CONCENTRATED SOLAR POWER PLANT PROPOSAL FOR BRAZIL– CSP

Abstract. *This article seeks the research exercise of technologies of electric power generation by solar concentration (CSP) in the world, intending to choose the one that is most applicable to construction in Brazil. Currently, several energy sources are presented in the Brazilian energy matrix, this research also aims to verify and identify the extent of renewable energies to the national reality. Through these studies, it will be possible to conclude the viability of CSP technologies to Brazil.*

Keywords: *Renewable Energy, Heliothermic Energy, Solar Tower, Solar Field, CSP, Solar Energy, Concentrated Solar Power.*

1. INTRODUCTION

Hydroelectric power has always been the huge importance for energy generation in Brazil, but large investments are needed with major environmental problems due to the huge flooded areas. Hydroelectric power plants also excel in gigantism and require high volumes of available water. Each year these water volumes are more and scarcer due to the use of the resource by the growing Brazilian population and the droughts that can provoke crises of electricity supply.

Currently in Brazil 62% of the installed capacity is generated by the hydroelectric power plants, a source that is expected to be fully utilized in the medium term according to the strategic analysis of the Brazilian government described by the Energy Research Company (EPE). In addition, the growth of the Brazilian economy demands an increase in the consumption of electric energy in several sectors. Electrical energy demand studies for the EPE for five-year horizon show that in the period from 2015 to 2020 the annual consumption of electricity will grow by around 4.0%, which may accentuate the problem of lack of energy in the medium term.

As a solution to these scenarios, there is a need to diversify the Brazilian energy matrix with new clean generation technologies of low cost and quick application. A probable way is to use the production of electric energy by means of solar because Brazil has its great territorial extension, abundance of solar radiation and lands at low cost.

There is a need to break the paradigm of innovative solar generation in Brazil and apply the best available technologies to increase the production of electric energy, as already done in wind and photovoltaic generation. This article intends to study the viability of the technologies of electricity generation by means of solar concentration, Concentrated Solar Power (CSP), innovative and applicable for interesting one for the Brazilian reality.

There is an unprecedented use of CSP energy in Brazil as well as in the world, which is a strong indication of the need to deepen knowledge through research. As in this decade, Brazil

experienced a crisis in the generation capacity of electric power the research of new technologies for solar energy generation may be a short-term solution for the increase on expected consumption.

As this article intends to be based on bibliographical references, a research is adequate within the expected periods since the author intends to specialize in renewable energies.

1.1 Objectives

1.1.1. General objective

This is an article to study through bibliographical and documentary references the new technologies for Brazil to generate energy through concentrated solar energy (CSP) to improve the diversification of the Brazilian energy matrix.

1.1.2. Specific objectives

To obtain the general objective will be researched the Brazilian energy matrix and the generation capacity per technologies. Confirm what are the renewable energy operating in Brazil and installed power of each. Research the installing costs of each technology in Brazil. Verify which as CSP generation technologies available in the world, their capacities and efficiencies as power generating plants. Research the cost of implementing CSP reference plants. Check which CSP technology is most applicable to Brazil. Research which and how many power plants in the world for the chosen CSP technology. Describe the chosen CSP technology and, finally, the results and conclusions of this Technical Reports.

1.1.3. Search Object

This article proposes research of new types of CSP solar power plants to improve the lack of electric energy saturation of Brazilian water potential.

1.1.4. Delimitation

This research delineates only CSPs technologies, other renewable solar technologies have not been researched. It also provide costs like implementing renewable energy in Brazil to compare of existing CSP generation technologies in the world. Final costs to Consumer were not raised.

1.1.5. Search Limitations

This article is a database and surveys, magazines, trade magazines, documents that tell you about the technologies available in the world.

1.2 Hypotheses

Energy generation via CSP has a great possibility of being implemented in Brazil as well as a wind generation already and photovoltaic. As well as thermoelectric power plants, the CSPs have possibility of being used in complementary generation the Brazilian hydroelectric plants, diversifying the Brazilian electric power generation matrix.

In Brazil, there are no CSP plants generating electricity. The CSPs available in the world, which seems to be more appropriate, is a solar tower with heliostat field for large electric power generation. It intends to prove that the CSP plants are viable for energy generation in Brazil.

1.8 Justification

The generation of solar energy via solar tower and CSP may replace the construction of new thermoelectric plants in Brazil with lower implementation and operational costs with an advantage of being a renewable energy source. The Brazilian energy matrix will become more diversified and with the possibility of increasing the share of renewable energy. It has a possibility of using unproductive areas of the north eastern semiarid region with land at low cost and possibility of social improvement in the areas where the generation will be produced.

1.9 Structure of Work

A structure of this article is detailed to facilitate the reader's understanding and according to ABNT Brazilian Standards being organized in Abstract, Introduction (Cap.1), Bibliographic References (Cap.2), Development (Cap.3) , Results (Chap. 4) and Conclusions and Discussions (Chap. 5).

2. THEORETICAL BACKGROUND

2.1. Electricity Generation in Brazil

Nowadays in the world society, the use of electric energy is relevant. It is no different in Brazil where the Brazilian energy matrix is formed by five different sources where hydraulic generation is predominant (TOLMASQUIM, 2016). The Brazilian Government's Energy Research Company (EPE) presents the technologies involved in the generation of electricity and respective installed capacity in 2015. It is possible to note the participation of the renewable technologies in addition to Biomass (BIO), small hydropower (PCH), Wind (EOL) and Solar (SOL) has installed capacity with 16% (TOLMASQUIM, 2016).

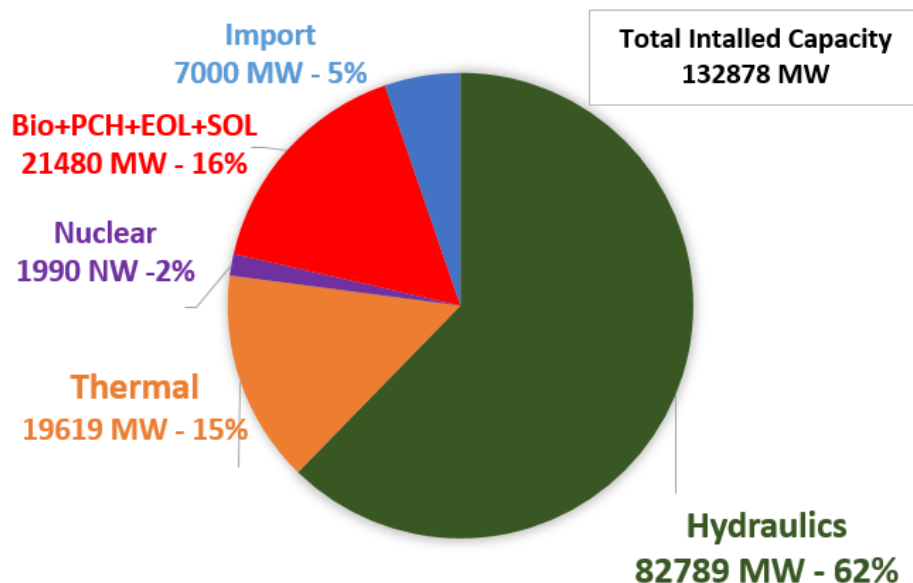


Figure-1 Brazilian Energy Matrix (EPE, 2016 - customization by author)

2.1.1. Renewable Power Generation in Brazil

Today in Brazil we have as main renewable and innovative sources for generation via power plant the commercial technologies that are the PCH (Small Hydroelectric), Biomass, Wind and Photovoltaic and in development: Heliotermic and Oceanic (TOLMASQUIM, 2016). For these renewable sources, the National Electricity Agency (ANEEL) indicates that Brazil has 4,660 undergoing operations, totalling 152159030 KW of installed capacity (ANEEL, 2017). Table 1 presents the plants in operation and construction in Brazil.

Table-1: Renewable energy Enterprises in Brazil in 2017 (ANEEL 2017 - Adaptation of the author)

Type of Power Plant	In Operation			In Construction		
	Quantity	Power (kW)	%	Quantity	Power (kW)	%
Hydropower	609	534999	0.35	3	4048	0.04
Wind	425	10405242	6.84	161	3748700	32.84
Small Hydropower	436	4978243	3.27	29	374791	3.28
Photovoltaic Solar	44	23761	0.02	37	1063400	9.32
Hydroelectric	219	93216340	61.27	6	1922100	16.84
Thermoelectric	2924	40984495	26.94	31	2950506	25.85
Thermonuclear	2	1990000	1.31	1	1350000	11.83
Total	4659	152133080	100	268	11413545	100

The costs of renewable and innovative energies in Brazil can be observed in Figure-2, based on the Brazilian Renewable Energies magazine (MARIANA SALES RANGEL, 2016).

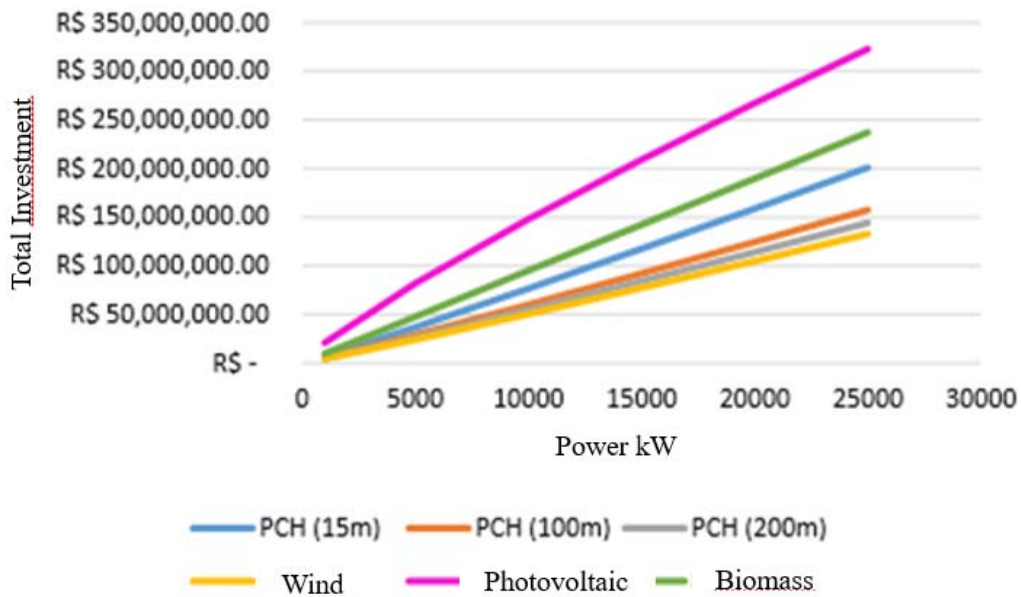


Figure-2: Cost of Capital (Installation) of Renewable Energies in Brazil (Brazilian Magazine of Renewable Energy)

2.2. Solar Power Generation Capacity CSP in the World

The countries that developed technology for heliothermic sources CSP are Spain, USA, South Africa and India (CARDOSO, 2016). Given that, the installed generation capacity in the world can be observed in Figure-3. In Brazil, there are no CSP commercial power generation plants (REN21, 2016).

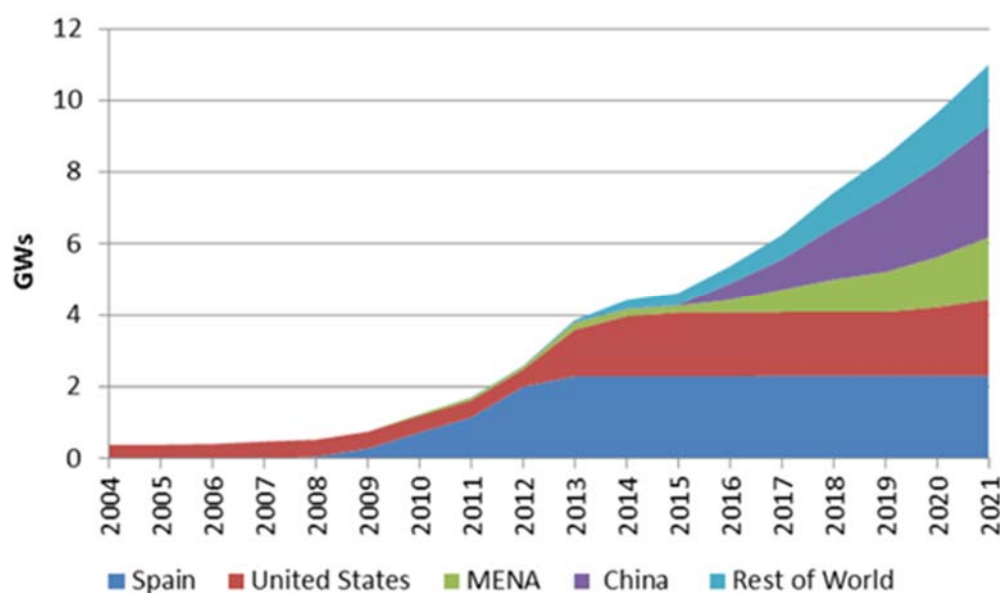


Figure-3: Installed Global Capacity CSP (Report REN 21, 2016)
* Mena (Middle East and North Africa)

2.3. Types of CSP Solar Power Plants Technologies in the World

The Figure-4 presents the main technologies applied for concentrators solar power plants commercially used in the world:

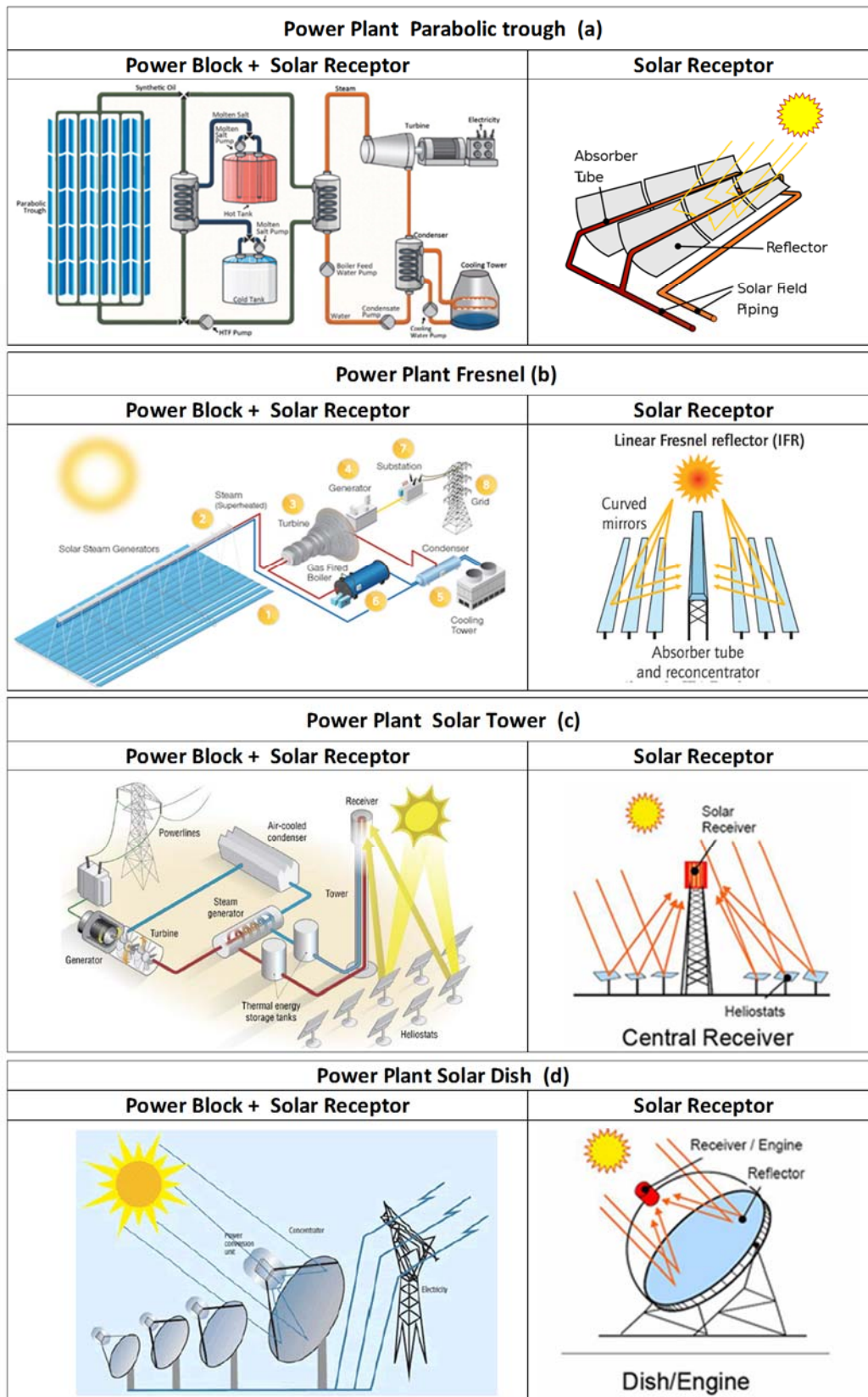


Figure-4: CSP Power Plant Schemes Source: (a): (BOUKELIA T,E, 2013), (b): (SILVESTRE 2016), (c): (US Department of Energy), (d) : (STANFORD UNIVERSITY, 2017) - Adapted by the

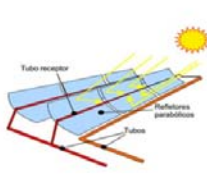
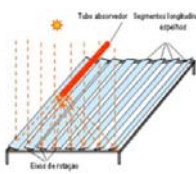
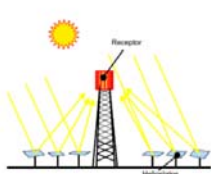
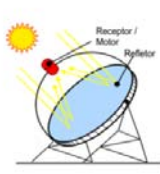
author

In the world, power plants use concentrators in the generation block. They are type: Parabolic Trough, Fresnel, Parabolic with Sterling engine and Central Tower (MARANHÃO, 2015). These technologies are called Concentrated Solar Power (CSP) (G. O. PRADO, 2014). In Figure-4 the scheme of these technologies are shown less than the parabolic concentrate that has direct power generation without a power plant.

2.4. Comparison of CSP Plants in the World

Table-2 presents comparisons between the main CSP technologies in the world with their main technical characteristics in summary form (SILVESTRE, 2016), as well as implementation costs and quantity of power plants (NREL, 2016).

Table -2: Comparison of CSP Plants in the World (SILVESTRE 2016) - Adapted by the author (*): (NERL,2017) - Adapted by the author

	Parabolic trough Tube Concentrator	Linear Fresnel Tube Concentrator	Solar Tower - Heliostats Concentrator - Receptor	Disc Parabolic Sterling Engine - Receptor
Solar Concentration				
Typical Capacity	100-300 MW	10-200 MW	10-200 MW	0,01-0,025 MW
Receptor	Mobile	Mobile	Fixed	Mobile
Operational Temperature	350-450 °C	390 °C	250-565 °C	550-750 °C
Efficiency	14-20 %	18%	25-35%	30%
Water Consumption	Yes	Yes	Yes	No
Cycle of Power block	Rankine Sp/ Bryton	Rankine St	Rankine Sp	Stirling/ Bryton
Heat Stock	Medium High	Medium	High	Not Applicable
Terrain Declivity	<1-2%	<4%	<2-4%	10% +
Cost of implementation USD Million / MW *	5,714	3,222	5,836	-
Reference Plan *	Mojave Solar (EUA) Project - 2015	Kogan Creek (AU) Solar Boost -2016	Ivanpah Solar (EUA) Electric Generating System -2014	Maricopa Solar (EUA) Project -2011
Number of power plants *	96	15	32	2

2.5. Choose of Location

For the installation of a CSP-type solar power plant, it is necessary to analyze the highest average isolations in Brazil to obtain the best process efficiency, due to the higher amount of solar

radiation absorbed at the ground level (CARVALHO, 2016). Through the radiation presented in the Solarimetric Atlas of Brazil in Figure-5, it is possible to verify the annual average insolation for country (OLIVEIRA, 2016). The highlight the semi-arid Northeast with 982,563.3 km² according to the Brazilian Institute of Geography and Statics (IBGE, 2016) with insolation of 20 MJ / m² (5.7 kWh) (MARANHÃO, 2015).

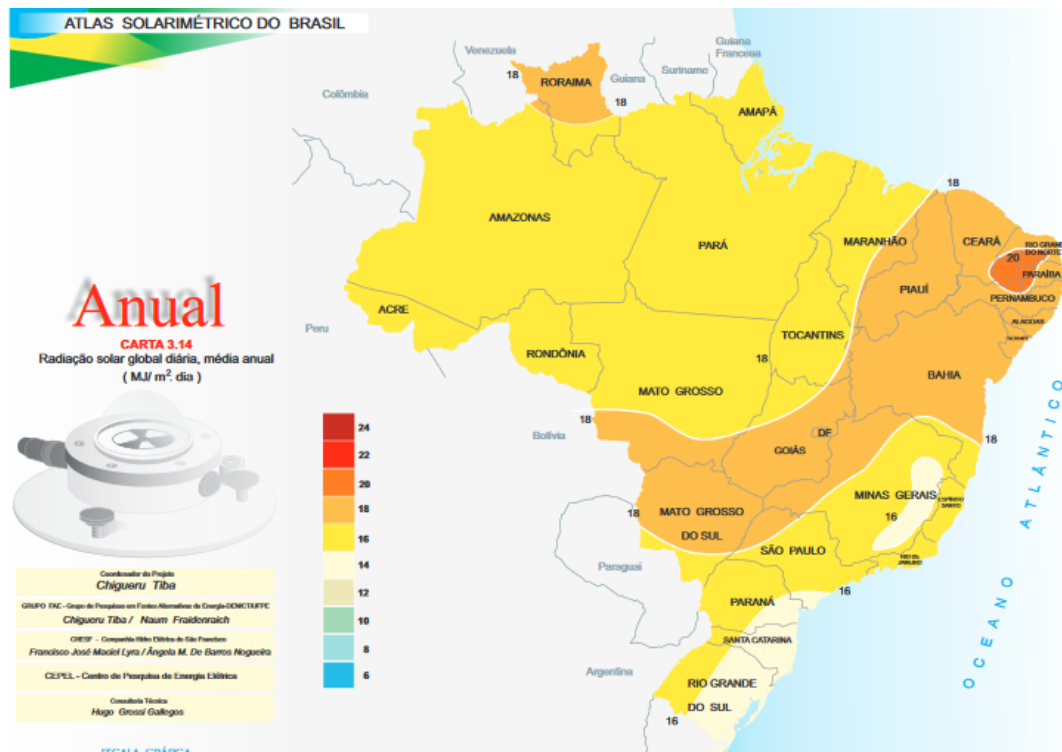


Figure-5: Brazilian Solarimetric Atlas (CEPEL,2016)

2.6. Choice of Technology for Generation of Solar Electric Energy CSP in Brazil

Generation by Solar Tower is the most promising according to Maranhão (2015) conclusion: "High temperature thermal energy storage represents the biggest advantage of solar tower systems when compared to other existing solar concentration technologies because it increases the capacity factor and allows a flexible generation strategy to maximize the value of the electricity generated, as well as to achieve higher levels of efficiency. High temperatures can allow greater steam cycle efficiency and reduce water consumption for condenser cooling. They also allow for greater temperature differences in the storage system, reducing costs or allowing more storage at the same cost. These systems are also the best option for locations with rough terrain, since heliostats can be arranged individually. (MARANHÃO, 2015)

In addition, it is possible to generate power at night by up to 8 hours up due to the possibility of heat storage of heat transfer fluids in tanks (SCIENTIFIC AMERICAN MAGAZINE, 2016). With the combined heat cycle with heat storage is possible for up to 15 hours without the need for solar radiation (IRENA, 2016).

2.7. Survey of CSP solar power plants in the world

Currently in the world today, there are 14 Power Plants with Solar Tower generating commercially 614 MW as published by the North American Department of Energy (NREL, 2017). In Table-3, the summary is presented with the five main operational and under construction generators in the world and their capacities. (NREL, 2017).

Table 3: CSP - Five major Solar Tower power plants in the world. (NREL-U.S Department of Energy, 2017) - Adapted by the author

Index	Capacity MW	Power Plant	Contry	Location	Beginning of Operation
Five major CSP operational power plants with Solar Tower					
1	347	Ivanpah Solar Electric Generating System (ISEGS)	EUA	San Bernardino County, California	2014
2	110	CrescentDunes Solar Energy Project (Tonopah)	EUA	NyeCounty, Nevada	2015
3	50	Khi Solar One	Africa do Sul	Upington	2016
4	20	Planta Solar 20 (PS20)	Espanha	Seville	2009
5	19,9	GemasolarThermosolarPlant (Gemasolar)	Espanha	Fuentes de AndalucíaSeville	2011
Five major power plants under construction CSP with Solar Tower					
1	260	Copiapó	Chile	Copiapó	2019
2	200	Golmud	China	Golmud (Qinghaiprovince)	2018
3	135	HuangheQinghaiDelingha DSG Tower CSP	China	Delingha (Provincia de Qinghai)	2017
4	134	NOOR III	Marrocos	Ouarzazate	2017
5	121	AshalimPlot B (Megalim)	Israel	Ashalim (Deserto de Negev)	2017

2.8. Simplified Operation of CSP Power Plant with Central Tower

The main systems for electric power generation in the solar tower are the Heliostats. As Figures-5 and 6 presents a one side the support structure and other side reflective film. They fulfill the function of reflecting the solar radiation for absorption by the central Receiver in the Solar Tower. (SILVESTRE, 2016).

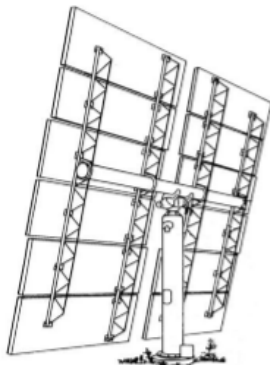


Figure-5: Heliostat structure (ESTAQUIO,2014)



Figure-6: Heliostat Mirror (PSA ,2017)

This equipment forms the Field of Heliostats as presented on Figure-7and 8, responsible for reflecting the maximum possible radiation to the Solar Receiver through an automated form (Solar Tracker) following the solar position is during all the duration the day or for each time of the year, equinox to solar solstice (ESTAQUIO, 2016).



Figure-7 : Heliostats Field

(ABENGOA PS20,2017 – Divulgation)

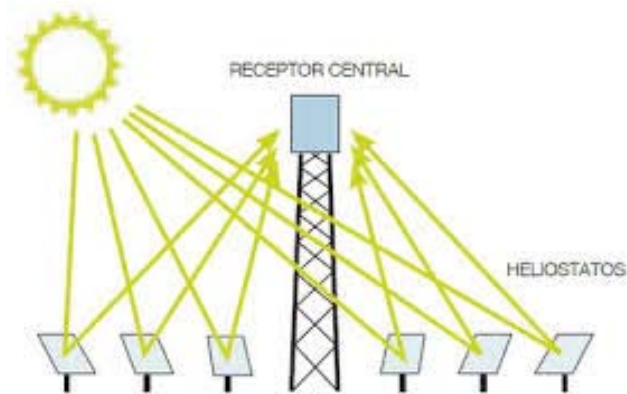


Figure-8: Solar Tower Receptor Scheme

(US Department of Energy,2017)

After the capture of the radiation by the Central Receiver of the plant, the heat exchangers coupled transformed the heat of irradiation in thermal conduction and convection transferring it to cold saline fluid and increasing its temperature. (CARVALHO, 2016). These are hot are transferred to a thermally insulated stock tank where provision for electric power generation (AMERICAN SCIENTIFIC REVIEW, 2016). This is the basic solar heating cycle of the plant, it is worth noting that it is given to the salt stock and it is possible to generate electric energy or the presence of solar radiation (IRENA, 2012). Figure-8 shows the basic scheme of how this process happens in the plant.

This process is also very similar to a conventional thermoelectric power generation, where a heat exchange receives energy from the heated molten salt of the generation block releasing heated steam for power block flowing water vapor to a steam turbine and electric generator (SILVESTRE, 2016). This generator will supply electricity to the distribution network and to final consumers

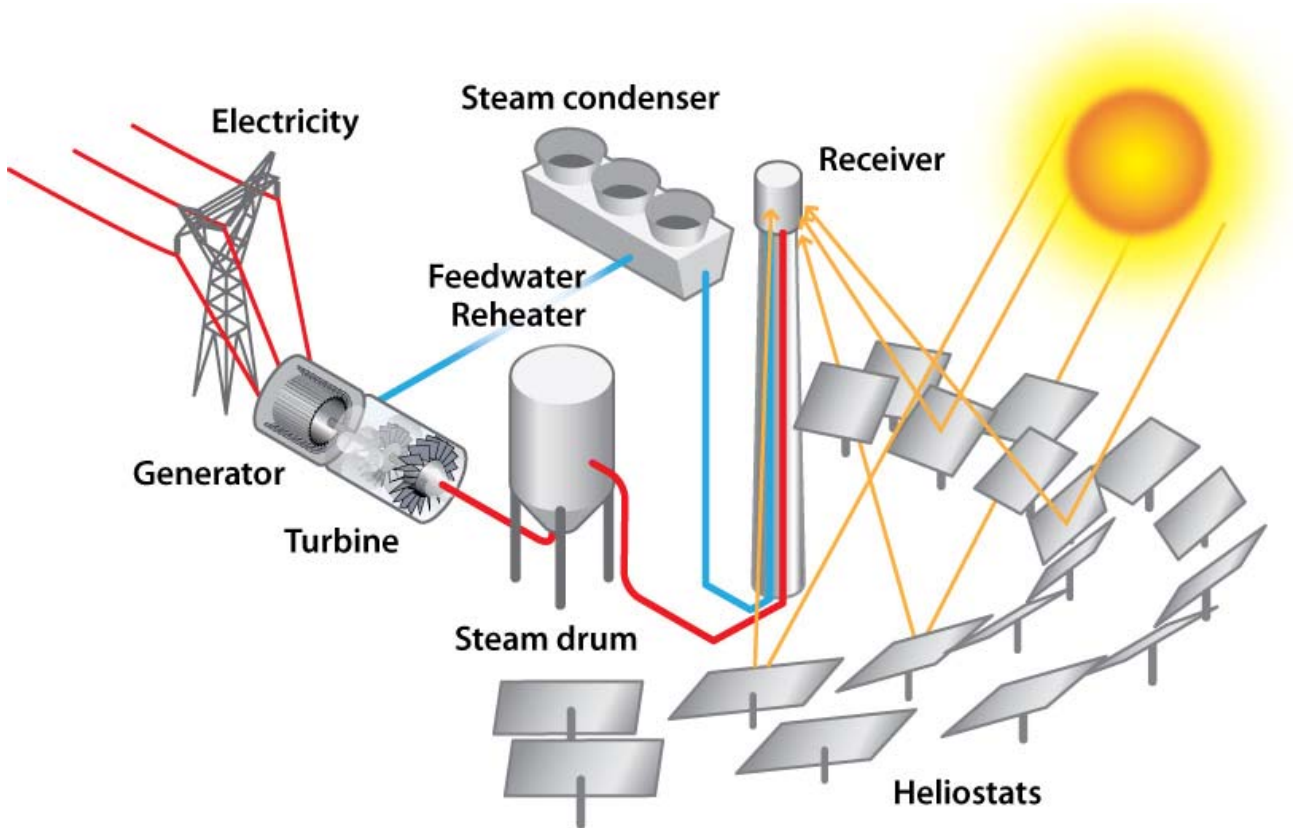


Figure-9: Solar Tower Power Plant Scheme (US Department of Energy, 2017)

As state-of-the-art for high-capacity Solar electric generation is is the largest CSP Solar Tower in the World in California Desert, the Ivanpah Solar Electric Generating System, with 177,000 15m² mirrors (ASME Magazine, 2013) and generation of 377 MWh (NREL, 2017), through three towers of generation of 129 m of height, installed in an area of 2,600,000 m² and with capacity to supply 140 thousand American residences (Exame Magazine, 2013). In order to have a comparison the thermoelectric unit (UTE) of the city of Manaus generates 136 MWh and that of Piratininga in São Paulo 190 MWh (Petrobras, 2017).



Figure-10: Ivanpah Solar Electric Generating System – (DAILYTECH MAGAZINE, 2017)

3. Development

3.1. Research Methodology

This research is of a basic nature because it describes processes that contribute to increase knowledge about the subject of the article, with a qualitative approach, since the way of approach and questioning has sensed to stimulate the reader to interpret the concepts, phenomena presented in the real world. The objective of this research is exploratory. (CERVO, 2016)

3.2. Research method

The research method was developed to deepen the knowledge trough theses, monographs, articles, governmental information atlas or official information were collected, based on the literature available and referenced in the article, thus consolidating results and conclusions. With the bibliographical reference, the available references was researched less than 5 years of publication and old publications up to 10 years only if necessary.

4. Results

For the generation of electric power by solar renewable source of high capacity generation the most viable technology to Brazil is CSP by Solar Tower. This power plant should preferably, be installed in the northeastern semi-arid region where the highest irradiations of 20 MJ / m² are found, but it is also feasible in regions ranging from Northeast to Southeast Brazil, above 12 MJ / m².

The average generation capacity of 250 MW can reach close to 400 MW, partially replacing the traditional 200 MW thermal power plants with the advantage of renewable energy technology. This energy can still be transmitted to the whole country due to the current distribution network interconnection.

CSP Renewable Energies are expected to grow from 6 GW in 2017 to 10 GW in 2020 due to new global investments, highlighting Chile and China with new Solar Tower Plants. Due to the CSP technologies, being recent and no such plant is operational in Brazil, this article has a limitation on the number of monographs and articles presented of Brazilian origin.

5. Conclusion

It is possible to note that the Brazilian energy matrix is diversified, but renewable and

innovative energies correspond to only 15% of the installed electric generation capacity, as opposed to 64% of the installed generation that is hydro origin of the large hydropower plants. It is a fact that the Brazilian hydraulic resource is tending to stagnation due to the population increase, the number of hydroelectric plants already installed in rivers and the water regime, where periods of drought in the whole territory can make the generation compromised.

Innovative renewable energies can be a solution of this scenario with possibility of technological maturity in a short time. In Brazil in 2017 we highlight the operation of Wind Power with 425 wind farms in operation generating 10.4 GW (6.84%), with a strong growth in the share of the energy matrix and Photovoltaic with 44 plants generating 23.7 MW (0, 02%) and the Small Hydroelectric Power Plants (PCH) with 436 plants and 4 GW (3.27%). As a comparison, the high-capacity thermoelectric plants generate 40.9 GW (26.84%), that is, Brazil favors the thermoelectric plants for the generation of additional hydroelectric plants.

Researching the implementation costs of the power plants was obtained that Wind Energy 2000 R\$ / KW generated and Photovoltaic 13000 R\$ / KW, denoting good scale of Wind Energy production in Brazil. Comparing to the typical thermoelectric plant, the cost is R\$ 1666 / KW. In other words, the thermoelectric plant has the lowest implementation cost. It is worth noting that operating and selling costs to the consumer were not raised.

There are 04 types of technologies for the generation of renewable electric energy in the world by solar concentration or "CSP". Its technologies are defined by the generation blocks of energy that are of the type are Parabolic Trough, Fresnel, Solar Tower and Parabolic Disc. The two technologies applicable to Brazil for the generation of electric energy are those of Solar Tower and Parabolic Trough according to Table-2 research due to their favorable characteristics presented. Both are able to make high capacity generation up to around 300 MW or more, even without the incidence of solar radiation, continue to operate due to the existence of tanks for heat stock, that is, generate electricity at night. In addition, both have good amount of plants in operation or under construction in the world being 96 for gutter, technology in commercial operation older and 32 (since 1997) for solar tower newer technology (since 2007) demonstrating solidity of generation comparing with the other two CSPs. Still, both have opportunities to improve efficiency, especially Solar Tower Power Plants and Parabolic Concentrator technologies. Fresnel and Parabolic Concentrator with Sterling engine technologies do not have these characteristics adequately and therefore are not applicable.

Analyzing the generation by Solar Tower also has a number of advantages in relation to the Parabolic Trough, such as higher operating temperature (565 ° C versus 450 ° C), high heat storage in the tanks, possibility of operation in more rugged terrains , a similar cost of implementation (R \$ 5836 / KW versus R \$ 5,714 / KW) and mainly the plant's efficiency (35% vs. 20%).

The implementation costs for CSP Solar Tower Power Plants are high according to North American values for Brazilian reality, compared to wind and thermoelectric technologies, but lower operating and consumer costs are expected. In the world, energy deployment costs tend to decline significantly by 2020. Nor is it certain that US costs are compatible with Brazilians, which are substantially lower.

It is worth remembering that the Solar Tower can generate electricity at night (up to 8h), which the Photovoltaic Power Plants do not perform. Wind power plants only generate about 40% of their useful time and the Solar Tower can generate up to 20 hours with heat stock and with mixed cycle with Natural Gas it reaches 24 hours. So the economy by scale is more applicable to the Solar Tower than Wind and Photovoltaic for cost reduction.

Therefore, the Solar Tower CSP Technology is better suited to Brazil and can be used in a renewable way in low-cost unproductive lands in the semi-arid northeast region of maximum vertical solar radiation.

5.1. Recommendation of future studies

The appropriate survey of operating costs and consumer energy prices of the Solar Tower Plant applied to the Brazilian reality. It is also imperative to lift losses Solar Tower Plant, with solutions for improvement with the purpose of reducing the costs of implementation and operation.

References

ASME Magazine-The American Society of Mechanical Engineer Magazine, Catching-the-Sun, 2013

Cervo A.L., Metodologia Científica, Pearson Prentice Hall, 2006.

Agencia nacional de energia elétrica – Aneel, Capacidade de instalada de energias renováveis no Brasil , 2017.

Bezerra P. H., AGRENER GD 2015, 10º Congresso sobre Geração Distribuída e Energia no Meio Rural, USP, São Paulo, 2015.

C.M. de Oliveira Filho, Metodologia Para Estudo de Implantação de Uma Usina Heliotérmica De Receptor Central No Brasil. Engenharia Elétrica Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2014.

C.C. Carvalho Fontes Heliotérmicas: Um Estudo Sobre o Funcionamento e o Potencial de

Implementação no Brasil. Departamento Acadêmico De Engenharia Elétrica, Universidade Tecnológica Federal do Paraná, 2016.

California Energy Commission - Ivanpah Solar Electric Generating system, 2017.

G. O. PRADO, Estado da Arte Em Tecnologias De Captação da Energia Solar Para Fins Térmicos. In: XX COBEQ, Congresso Brasileiro de Engenharia Química,, Florianópolis.2014.

Instituto Brasileiro de Geografia e Estatística – Áreas Especiais

IBGE<<http://www.ibge.gov.br/home/geociencias/geografia/semiarido.shtm?c=4>> Acesso 07 /04/ 2017.

IRENA - Renewable Energy Technologies: Concentrating Solar Power, 2017.

J.V.C.S., Eustáquio. Simulação e Análise do Comportamento do Campo de Heliostatos de uma Central de Concentração Solar Termoelétrica de Receptor Central. 2011. 89p. Tese de Mestrado Integrado. Engenharia Mecânica. Universidade do Porto. Faculdade de Engenharia, Cidade do Porto, Portugal, 2011.

M.T. Tolmasquim, Energia Renovável: Hidráulica, Biomassa, Eólica, Solar, Oceânica, Empresa de Pesquisa Energética, EPE, Ministério das Minas e Energia : Rio de Janeiro, 2016.

M.T. Tolmasquim ,Projeção da demanda de energia elétrica 2016 a 2020 , Empresa de Pesquisa Energetica EPE, Ministério das Minas e Energia : Rio de Janeiro, 2016,

NREL, National Renewable Energy Laboratory - U.S Department of Energy ,Power Tower Projects, 2017

NREL, National Renewable Energy Laboratory - U.S Department of Energy, NREL/TP-5500-67464 - Concentrating Solar PowerGen3 Demonstration Roadmap, 2017.

.Oliveira E.B., Atlas Brasileiro de Energia Solar, São Jose dos Campos , CPTEC, Centro de Previsão de Tempo e Estudos Climáticos do INPE , Instituto de pesquisas Espaciais e UFSC, Universidade Federal de Santa Catarina. 2016.

Petrobras - Usina Temoelétrica de Piratininga <http://www.petrobras.com.br/pt/nossas-atividades/principais-peracoes/termeltricas/piratininga.htm> Acesso 12/ 05/ 2017

Rangel M.S., Análise comparativa de custos e tarifas de energias renováveis no BrasilRevista Brasileira de Energias Renovaveis , 2016.

Revista EXAME, Maior usina solar do mundo começa a gerar eletricidade,

<http://exame.abril.com.br/economia/maior-usina-solar-do-mundo-comeca-a-gerar-eletricidade/>,

Acesso 07/ 04/ 2017

Silvestre , Desenvolvimento de Heliostatos para Geração Heliotermica em Torres Solares . Tese de Mestrado Integrado. Universidade Federal da Paraíba, João Pessoa, 2016.

Scientific American Magazine, New Concentrating Solar Tower is Worth its Salt with 24/7 Power ,2017.

Solar Energy History Article<<http://www.zero-point4energy.com/solar-energy-history.html>> Acesso 07/ 04/ 2017.

Secom, Governo de Sergipe, Usina Termoelétrica de Sergipe será a maior da América Latina

http://www.nenoticias.com.br/98393_usina-termoeletrica-de-sergipe-sera-a-maior-da-america-latina.html, Acesso 17/ 04/ 2017

. Zervos A., Renewables 2016 Global Status Report– REN21, National Technical University of Athens, 2016.