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Review of Technologies and Optimization Methods for Integrating Renewable Energy Sources and storage of India Market

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Abstract: *- In This paper, A Energy is a vital input for social and economic development. As a result of the generalization of agricul-tural, industrial and domestic activities the demand for energy has increased remarkably, This has meant rapid grower in the level of greenhouse gas emissions and the increase in fuel prices, India is gradually shifting focus toward its renewable energy resource more effectively, Despite the obvious advantages of renewable energy, it presents important drawbacks as most renewable energy resources depend on the climate, which is why their use requires technical literature about optimization techniques applied to micro grid planning have been reviewed and the guidelines for innovative planning methodologies focused on economic feasibility can be defined. This paper presents a review of the current state of the art in computational optimization methods applied to renewable and sustainable energy, offering a clear vision of the latest research advances in this field*

Keywords: - Renewable energy systems Optimization Multi-criteria decision analysis Design Planning Control

1. INTRODUCTION

In India, Concentrated Solar Thermal (CST) plants, which convert concentrated sunlight to heat and then to electricity, have the potential to be a substantial contributor of electricity generation. These plants usually incorporate some means of storing any heat that is not immediately converted into electricity in what is termed Thermal Energy Storage (TES). This stored heat can then be used to generate electricity at other times such as when it is cloudy or at night.

A renewable energy generation, including wind farms and residential rooftop photovoltaic systems maintaining grid stability is emerging as a critical problem in the short term.

However, research into optimal operation of solar thermal plants and optimal sizing of storage is still in its infancy. Furthermore, research into hybridized storage for CST which incorporates both thermal and electrical storage controlled from the one CST plant is also lacking despite extensive research into electrical storage options for other variable generation.

The improvement of renewable energy technologies will assist sustainable development and provide a solution to several energy related environmental problems.

This paper considers the incorporation of electrical storage with a solar thermal plant as it may still prove advantageous despite there being little or no identified literature considering a solar thermal plant with both thermal and electrical storage within its control. Figure 1 depicts a generalized solar thermal plant that incorporates thermal energy storage with electrical heaters and electrical energy storage in the plant design. Such a plant would then participate in the supply of electricity to the grid within the Indian National Energy Market (NEM).

The remainder of this paper is segmented into two main parts: The presents a brief overview of renewable energy technologies with a focus on concentrated solar collection, thermal and electrical storage, as

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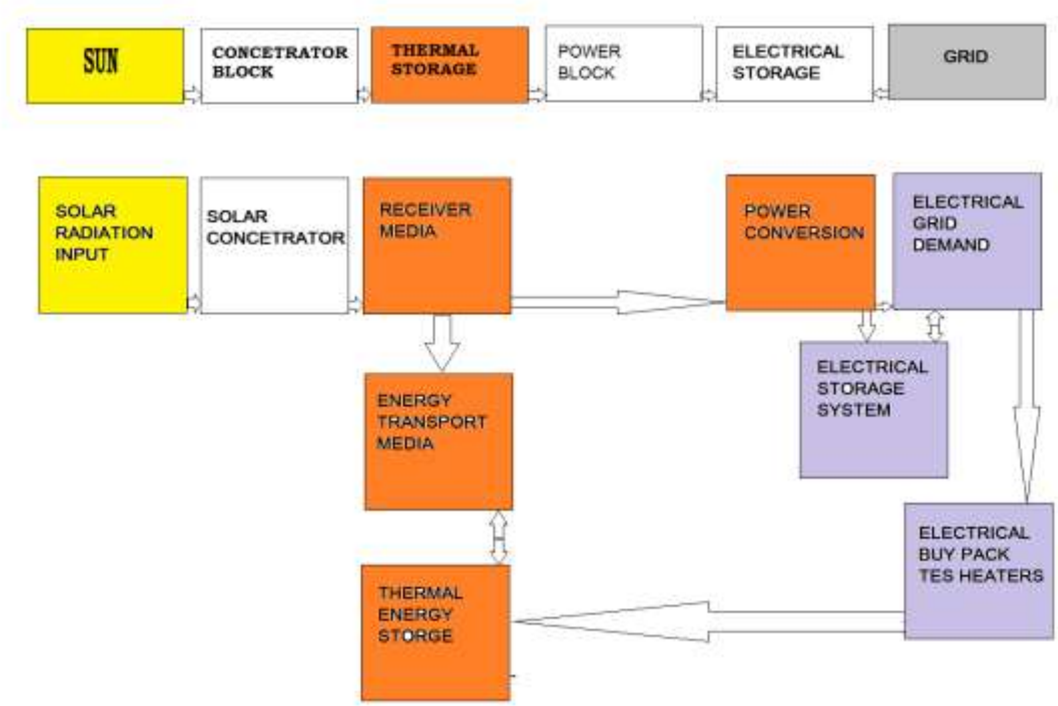
depicted in Figure presents a survey of modelling, optimization and control methods relating to CST with storage. Concluding remarks and future research directions.



1.1 SOLAR POWER IN INDIA

In July 2009, India unveiled a US$19 billion plan to produce 20 GW (20,000MW) of solar power by 2020. Under the plan, the use of solar-powered equipment and applications would be made compulsory in all government buildings, as well as hospitals and hotels. On November 18, 2009, it was reported that India was ready to launch its National Solar Mission under the National Action Plan on Climate Change, with plans to generate 1,000 MW of power by 2013.

India's largest photovoltaic (PV) power plants

- Reliance Power Pokaran Solar PV Plant, Rajasthan, 40MW 02011-06 June 2011 Commissioning in March 2012
- AdaniBitta Solar Plant, Gujarat, 40MW 02011-06 June 2011 To be Completed December 2011
- Moser Baer - Patan, Gujarat,30MW 02011-06 June 2011 Commissioned July 2011
- Azure Power - Sabarkantha, Gujarat, 10MW 02011-06 June 2011 Commissioned June 2011
- Green Infra Solar Energy Limited - Rajkot, Gujarat, 10M W 02011-11-29 November 29, 2 011 Commissioned November 2011

The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 1500–2000 sunshine hours per year (depending upon location), which is far more than current total energy consumption For example assuming the efficiency of PV modules were as low as 10%, this would still be a12 thousand times greater than the domestic electricity demand projected for 2015. Fig shows the average solar radiations receiver by different regions in India.

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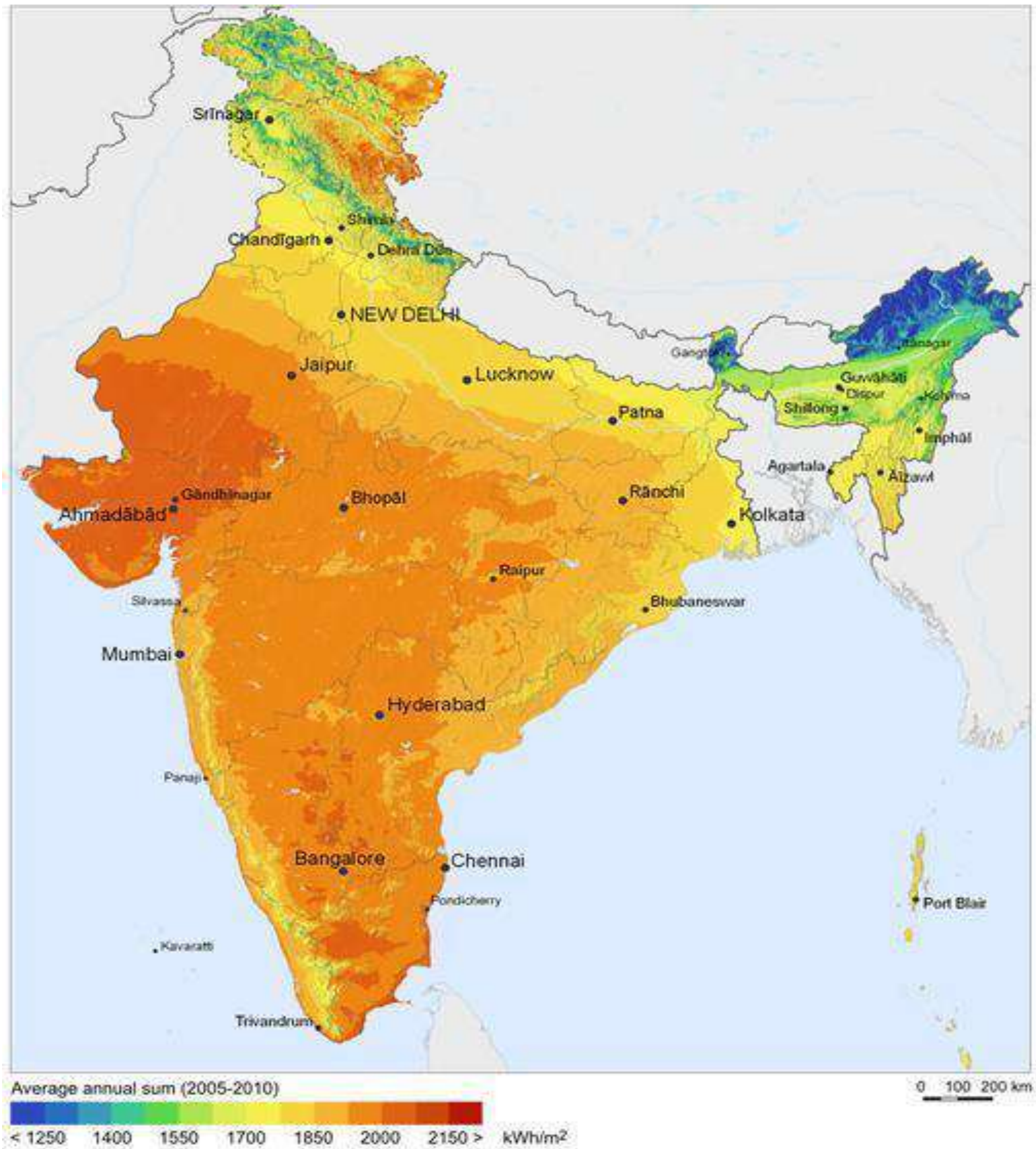
Gujarat government has signed a MoU with Clinton Foundation to build the world's largest solar-power plant in the region. The 3,000-megawatt plant near the border between India and Pakistan would be one of four planned by the initiative, a William J. Clinton Foundation program to promote renewable energy. The other proposed sites are in California, South Africa, and Australia.



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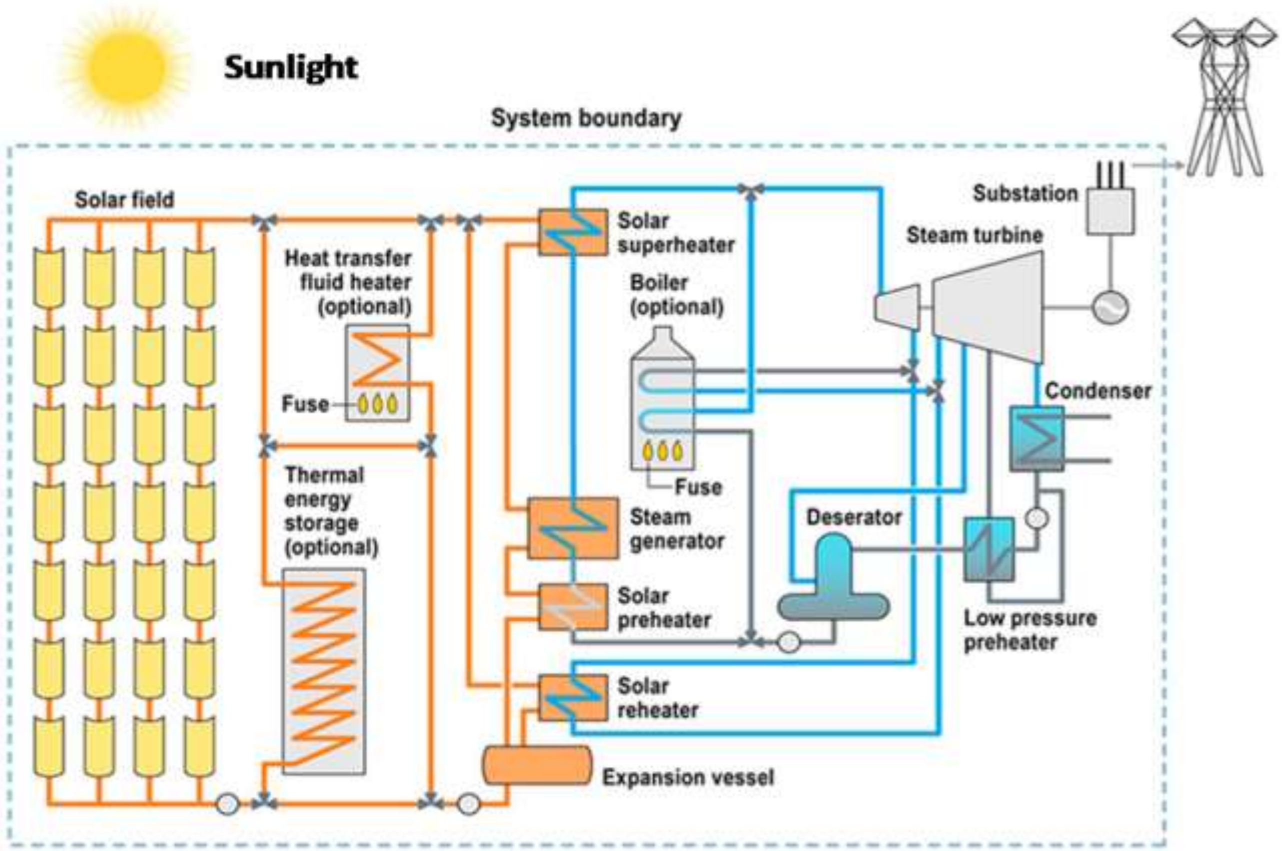
II. TECHNOLOGIES FOR RENEWABLE ENERGY GENERATION AND STORAGE

This section provides a sampling of the literature for descriptions of the various CST technologies and on the use of thermal and electrical storage with renewable energy generators. Figure shows the solar-field and power-block components of a parabolic trough CSP plant, as well as optional components including thermal energy storage and a natural gas backup boiler.

The solar-field components can be oversized relative to the power block so that energy captured during the day can run the power block and provide additional heat energy to the thermal storage medium. This stored energy then can be used to run the power block during cloudy periods and at night, significantly increasing the capacity factor of the CSP power block. Currently, CSP systems with more than 7 hours of thermal storage.



Parabolic trough systems were first commercialized in 1984 and account for 96% of global CSP deployment (NREL 2012). Power tower systems have a shorter operational history. Solar Two, a 10-MW power tower with 3 hours of molten salt thermal storage.

Several demonstrated CSP systems use natural gas for backup energy—like the solar energy generating systems (SEGS) plants but these are fundamentally different from new CSP designs where solar thermal energy is directly used to augment combined cycle natural gas generators or a coal generators.

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III. MODELLING AND OPTIMISATION: METHODS APPLICABLE TO CSP WITH STORAGE

This section presents a selection of papers related to the modelling of external parameters relevant to the operation of a CST plant. This is followed by a presentation of literature relating to the problem of optimization of CST plant and the use of storage in general.

3.1 External Parameter Modelling

Power generation from a CST needs to be framed within the context of:

I. The available solar resource, in terms of Direct Normal Irradiance (DNI)
II. The energetic demand from the grid and
III. The economic environment.

3.2 Models for Solar Irradiation

The energy source for a CST plant is direct solar irradiance. To manage a CST plant it is important to understand how solar irradiance will vary on different time scales, including short time scales (minutes), over which irradiance can be forecast with sufficient accuracy to maintain control over the plant, and longer time scales.

The review of solar irradiance models by Diagne et al. (2013) discusses the accuracy and the relative compu-tational requirements for predicting solar irradiance at various time horizons along with hybrid models for the combination of both very short term and longer term predictive models.

The work performed by Huang et al. (2013) gives an hourly one step ahead predictor for global or DNI, provided there is historical training data available, using a modified time series analysis method. Some work has also been performed to establish the diffuse fraction of solar irradiation (Boland et al., 2008) from which DNI can be inferred when only global solar irradiation historical data is available.

3.3 Models of Demand.

A comprehensive review of demand modelling for use with energy production world-wide is presented by Suganthi and Samuel (2012). This review dealt with short term to long term forecasting world wide using a variety of techniques.

Techniques by Magnano et al. (2008) were used for the synthetic generation of load or demand characteristics for South Australia. Magnano and Boland (2007) was used to support this work as demand variation is largely driven by temperature,time of day, day of week and month of year. Boland (2010) builds on both these previous works with two applications, one being a PV positioning optimization problem which also uses stochastic programming as described by Shapiro and Philpott (2007).

A description of a complementary method for short term load prediction using multiple linear regression methods based on month, hour, and temperature as the input variables. Models for Energy Spot Price Prediction. The revenue that can be generated by a plant will depend not only on the demand for electricity but also on the wholesale spot price, which varies every five minutes Kim and Powell (2011a) presents a zero moment method (Robbins and Monro, 1951) for the prediction of spot price fluctuations in energy markets.

3.4 Modelling and Analyses with Scenarios of Differing Penetration of Renewable Energy

The report by Denholm et al. (2013) discusses in some detail the operation of a CST within a scenario of 33% renewable energy supplier penetration. One of the main observations from this work was that with renewable energy at 33% of the total market, CSP with storage should be operated primarily to provide ancillary services for grid frequency stabilisation and ramp rate matching in order to provide maximum value to the grid. This work utilises the National Renewable Energy Laboratory (NREL) The article by Usaola (2012b) discusses similar grid stabilisation operation from a regulator or policy making perspective in the Spanish energy market with details of the model formulation and analyses presented in Usaola (2012a) for short term (2 day ahead) prediction of market behavior (demand and price). One of the key findings of Usaola (2012b) is that the Spanish market does not present the same opportunities for returns as the US market.

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A complementary report by Mills and Wiser (2012) compares the long-run marginal economic value of wind, single axis tracking PV, CSP without storage and CSP with 6 hours thermal storage in California for a 2030 scenario against the cost of operating a flat block fossil fuel generator of the same capacity, as the percentage penetration of all variable generation technologies is increased. The findings show that within the limited scope of their study, the marginal value of CST decreases less than that of PV and CSP without storage as the percentage penetration of variable generation increases and that the marginal value of CST remains higher than that of wind at all penetration levels.

3.5 Control and Optimization

Optimisation of a CST needs to consider the following:

- ✓ optimal control of an existing plant with storage systems to maximize revenue
- ✓ Optimal sizing of collectors and storage systems.

When considering CST operation within the context of the Australian NEM energy and ancillary services markets, dispatch bids are made at 5 minute intervals with half hourly clearing cycles. Though unique to the NEM, there may be benefits in developing methods applicable to the 5 minute time frame as evidenced in the report by IEMO (2012b) where one of the improvements in forecasting wind output is attributed to performing wind data analysis on the reduced interval size of 5 minutes from the previous 30 minute intervals.

Optimisation for Renewable Electricity Generation and Storage. Bazmi and Zahedi (2011) present a substantive review of optimization studies related to power generation and supply including:

I. Power supply and distribution
II. Power plant operation
III. Building energy consumption
IV. Industrial energy consumption
V. Power plants and carbon dioxide capture and storage (CCS) and vi) Renewable energy mix

A Examples of Optimisation for Renewable Electricity Generation Operation. Kim and Powell (2011b) presents a method to optimize the value of storage for an wind farm with associated pumped hydro storage system. The optimisation is performed by making short term decisions throughout the day as to store or dispatch energy based on an arbitrage mechanism for revenue (i.e. buy low, sell high). This problem is a variation of the well-known news vendor problem from operations research. The method assumes quantised state of charge levels for the storage element as well as operation within the discrete time domain and is limited to one day at a time optimisation, with all stored energy at the end of the day being of no value to the next day's trading.

An optimisation of a theoretical solar trough power plant with thermal store was presented by Morin (2012) considering the multivariate objectives for economic, energetic and operational aspects. The method uses multi objective optimisation enabled via Genetic Algorithms (GA) for traversing the solution space and presents a sensitivity analysis on various aspects of the plant operation. From an economic perspective the method optimizes an Leveled Cost of Energy (LCOE) parameter rather than the value that can be provided to an electricity market with fluctuating prices.. The key finding of this work is that an optimization across all aspects of the plant, collector, power block and storage determines a better optimum that the optimization of each of the components in isolation.

IV. CONCLUSIONS

This paper has presented a brief summary of technologies pertaining to the implementation of Concentrated Solar Power plants implemented with both thermal energy storage and electric storage systems as depicted in Figure 1.

The optimal operation and sizing of concentrating solar thermal plants with both thermal and electrical storage has not yet been studied comprehensively.

Two of the major findings from the identified literature at this point are, firstly that most, if not all analysis is performed on hourly time scales rather than the Australian NEM market clearance interval time of 30 minutes, nor

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at the bid interval of 5 minutes. Secondly, concentrated solar thermal generation with storage becomes increasingly viable as the use of renewable energy storage increases.

There are a number of opportunities for further research:

I. Evaluating the value of electricity buy-back into either the TES or into distributed ESS under the CST plant's direct control.
II. Conducting system control at the finer time scale of 5 minutes and
III. Making use of longer term weather predictions to better manage storage state over larger time frames.

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