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Quasi-economic Feasibility Studies of Solar Rooftops in Cities Using the Optimal- Case Fermi Estimation Technique

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Abstract: **— A large majority of the industrial and working population of developing countries like India live in cities, especially metropolitan centres like Bangalore. Also, a vast amount of power is consumed in such cities. These factors coupled with the ageing infrastructure of transmission and distribution systems in India give a highly unstable power system structure. Also, there is a vast distance between the load centres like the cities and the generating stations. The growing urban loads tax the already overloaded infrastructure and lead to increased loss, drop in reliability, increased failure rates and possibilities of blackouts and heavy maintenance cost. It also escalates the need for replacement. But given the current economic scenario, one can easily ascertain that such a nation-wide restructuring and replacement of power system hardware is virtually impossible. The best possible solution to such a techno-economic crisis is by making the consumers generate electricity locally, by means of rooftop solar panels (PV). But such a system is in its infancy around the world and not many residents can afford such a system today in India. A proposal is made, in this paper for the government to sponsor the setting up of solar PVs over every house that has the necessary minimum requirements. The economic analysis of such a decision has been made with a robust mathematical technique called the Optimal Case Fermi methodology. Also, the technical aspects of such a move, namely, the reduction in burden on the grid have been calculated.**

***Index Terms*—Optimal-case Fermi, Macroeconomics, Microeconomics, Solar rooftops, Quasi-Economic feasibility .**

I. INTRODUCTION

The Indian energy scenario today is such that most of the electricity consumed is from Thermal Power plants based on coal. Coal reserves have been expected to last not more than a century, nearly 110 years[1]. The current consumption of electricity from coal accounts for 61% of the total energy consumed.[2]. The rapid decline of air quality in India can be attributed to this, as one of the influencing factors. The carbon footprint of conventional coal based plants is too high to continue using it at such a high rate.

On another note, the transmission and distribution systems in India are very old and poorly maintained. The generating stations are typically several hundred kilometres away from the load centres. Also, the open energy markets allowing power trading share the same old T and D infrastructure of the government. Expansion of existing power projects does not lead to an expansion of existing T and D infrastructure. Only in rare cases will new lines be added to take the additional load. But the energy demand is constantly increasing, leading to increased wheeling of power across insufficient power system hardware. This causes a higher loss factor(almost 27%, highest in the world) and reduces system reliability. Last mile connectivity is also limited in newly developed areas in the outskirts of the city and in satellite towns.[3].

The above problems are combated by using solar energy generated locally. Solar energy has been hailed as the future of clean, sustainable and renewable energy for the world. One of the major reasons for this not being followed is that not many households can afford to install a solar plant on their rooftops and those that do, do not do it due to other constraints and a lack of awareness. The government has not implemented this project because of the heavy investments it needs to make, with an uncertain recovery. This paper analyses the energy scenario in Indian cities and gives payback period, grid parity, micro and macroeconomic studies along with technical improvements over the existing system.

II. INTRODUCTION TO THE OPTIMAL-CASE FERMI METHODOLOGY

The Fermi technique belongs to a class of mathematical and logical analysis tools that allow a complete system model to be built with minimal data based on logically valid and informed assumptions based on deductions, inferences and other such logical constraints. The Fermi methodology is, therefore, rarely used for any engineering problem due to its tendencies to allow drifts in accuracy and values of parameters. The conventional Fermi Approximation was carried out by Enrico Fermi, the famous theoretical physicist and has been named after him.[4].

The drifts in values and the inherent tendency for inaccuracy can be effectively reduced to near zero by using accurate and validated data from reliable sources. While it is necessary to opt for the conventional Fermi methodology for describing a system that does not exist at all[5,6], in the case of the solar rooftop discussed in this paper, almost all necessary precursor data is available.
Hence, the method loses its tendencies towards low levels of accuracy and will be able to provide results comparable to those obtained by complete theoretical predictions. This is the optimal performance case of the Fermi method and is, therefore called the Optimal-case Fermi.

III. DATA PRECURSORS TO THE FERMI MODEL

The entire analysis of the proposed solution is performed for the city of Bangalore. Hence, all data mentioned here are in accordance to the given city.
Bengaluru/Bangalore city has a total number of 23,77,000 houses.[7]. The minimum requirements for withstanding a solar panel on the rooftop includes RCC/Fired brick constructions and at least 50 square feet of roof space for actual mounting of the solar PV system. By eliminating all households that do not satisfy these conditions, the number of households that can actually implement this concept is found to be 16,21,000.[7]

Solar irradiance is measured in terms of "sun" units, where 1340W/m2 of surface irradiance is called 1 sun. The efficiency of a solar panel is taken to be 23%, which is an industry standard for crystalline cells. Also, the irradiance profile over a day is comparable to that of a positive half cycle of a sinusoid, albeit with variances in peak times. The output power profile over one typical day is also comparable and has been plotted for reference in Fig. 1.

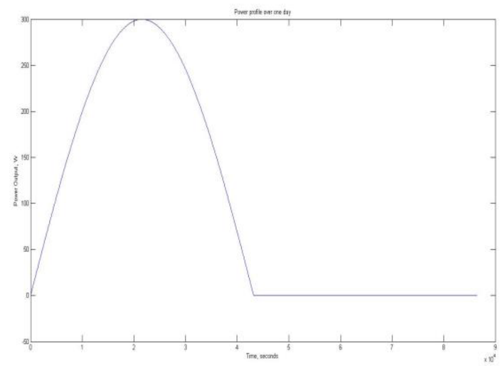

Fig. 1: Power output profile of a solar panel over one typical day.

The power profile has taken into account a panel efficiency of 23%, as mentioned above and is therefore, used for further calculations.

Average Power obtained in a day = $\frac{\int_0^{43200} P.dt}{\int_0^{43200} dt} = \frac{2.Pmax}{Pi}$

The average peak irradiance in Bangalore city has been found to be:

- 1 sun during the months of March, April and May (92 days)
- 0.4 sun during June, July and August (92 days)
- 0.7 sun during September and October (61 days)
- 0.75 sun for November (30 days)
- 0.85 sun for December, January and February (90 days).

IV. MICROECONOMIC STUDIES

Microeconomic studies have been undertaken over one household. They represent the differences that one given household experience because of the installation of Solar panels over their rooftop.

The peak power output with respect to solar irradiance is as follows. Pmax = 300W(1sun),120W(0.4sun),210W(0.7sun),225W(0.75sun),255W(0.85sun)
Their averages are as follows: Pavg = 191.00W(1sun),76.39W(0.4sun),133.69W(0.7sun),143.23W(0.75sun),162.33W(0.85sun) Now, considering that the power output of the panels is the average over the entire duration of 12 sunlit hours, the energy generated per day can be calculated to be:
Energy generated per day = [Pavg*12h] = 2.29kWh (1sun), 0.91kWh (0.4sun), 1.60kWh (0.7sun), 1.72kWh (0.75sun), 1.95kWh (0.85sun) respectively.
Therefore, total energy generated over one year may be calculated as [(2.29*92) +(0.91*92) +(1.60*61)+(1.72*30) + (1.95*90)]= 619.1 units which can be approximated to 620units/year Assuming that a unit costs □ 5, total money earned in a year = 620*5 = □ 3100
Therefore, payback time = 1,00,000/3100 = 32.25 years
But the total life time of a solar panel is 25 years, which implies that recovering the capital in the case of micro-economic systems is highly unlikely."

V. TECHNICAL ADVANTAGES

Total energy generated by the panels per year = 620*1621000 = 1005 million units
Daily power consumption of Bangalore = 42 million units[11]
Daily power consumption of Karnataka = 140 million units[11]
Total power consumed in a year by Bangalore = 15330 million units Total power consumed in a year by Karnataka = 51100 million units
Power consumed by Bangalore = 30% of the power consumed by Karnataka
If solar PV systems are implemented, they produce 1005/15330 which happens to be 6.56% of the demand of the city of Bangalore.
If implemented, the percentage power consumption of Bengaluru city with respect to Karnataka state reduces to 14325/51100= 28.06%. Therefore, there is a decrease in demand by 2%, which reduces the stress on a few power stations in the state to a very large extent.

VI. GRID PARITY

To achieve grid parity in 5 years, each unit has to be sold at 1,00,000/(620*5) = □ 32.26
To achieve grid parity in 10 years, each unit has to be sold at 1,00,000/(620*10) = □ 16.13
To achieve grid parity in 15 years, each unit has to be sold at 1,00,000/(620*15) = □ 10.75
To achieve grid parity in 20 years, each unit has to be sold at 1,00,000/(620*20) = □ 8.06.

VII. MACROECONOMIC STUDIES

As the microeconomic level of abstraction does not yield a positive result, the entire city is considered, with Government sponsored solar rooftops. The calculations are as follows:
Total investment to install solar PV systems in all suitable places is around □ 16210 crores
Profit earned by the government in 1 year, through solar PV is equal to □ 307.53 crores(If each unit is sold @□ 8.06, so as to achieve grid parity in 20 years).
It can be considered such that the profit cost invested in procuring the solar PV systems will be recovered in full during the first 20 years of operation and hence there is no profit. Profit is obtained only in the last 5 years of the life of the solar panel, after which the output from panels starts to deteriorate.
Therefore, profit that can be earned by the government, at the end of 25 years = (1005 million)*□ 3.06*5 = □ 4050.2 crores.

VIII. CONSUMER SIDE IMPACTS

If a 20 year grid parity is to be attained (□ 8.06 per kWh) with the proposed solar panel system, then, the increase in electricity bill per month would be
620*(8.06-5)/12 = □ 158.10 (assuming 1 unit costs □ 5, if drawn from the main grid)
620*(8.06-6)/12 = □ 106.43 (assuming 1 unit costs □ 6, if drawn from the main grid)
On an average, the increase in electricity bill every month would be around □ 132.26, which does not become a significant addition to the electricity bills of the residents of Bangalore city, as the average monthly bill range is already □ 900-□ 1200.

IX. RESULTS

The government sponsored solar rooftops have been proved to be economically viable in the macroeconomic sense. Grid parity of □ 8.06 is on par with the other solar power generating stations in India, and hence, viable. A fairly decent profit of □ 4050.2 crores is also achievable over the lifespan of the solar panels, 25 years. This system also has significant technical advantages, including reduction in burden on other thermal generating stations and the ageing T and

D infrastructure. The social and environmental impacts of such a scheme are fantastic, as one kWh of energy from a thermal power plant has a CO_2 emission of ~1kg. The installation of this system leads to prevention of emission of an unbelievable 1 billion kilograms of CO_2 every year.

REFERENCES

[1] https://www.worldcoal.org/coal/where-coal-found

[2] N Sasidhar,"Energy Resources in India", https://www.scribd.com/doc/58789317/Energy-Resources-in-India

[3]http://economictimes.indiatimes.com/new-sections/energy/the-loss-of-power/lifenologyshow/44083310.cms

[4] "Eyewitnesses to Trinity" (PDF). Nuclear Weapons Journal, Issue 2 2005. Los Alamos National Laboratory. 2005. p. 45. Retrieved 18 February 2014.

[5] Phalgun Madhusudan, Aditya Anilkumar, "Applications of Unconventional Statistical and Fermi estimation techniques to study the economic feasibility of micro and nano wind turbine power generation", at the International Conference on Chip, Circuitry, Current, Coding ,Combustion & Composites (i7C-2016), 10 November 2016.

[6] Phalgun Madhusudan, K Uma Rao ,"Applications of statistical models for assessment of economic viability of solar rooftops in India", at the National Conference on Challenges and Issues in Operation of Competitive Electricity Markets (CIOCEM 2016), conducted by IEEE PES and CPRI, Bangalore. 8 December 2016

[7] "Housing, Household amenities and assets – Key results from the census 2011", Directorate of census operations, Karnataka. www.censuskarnataka.gov.in

[8] Philip M Anderson, Cherie Ann Sherman, "Applying the Fermi estimation technique to business problems", Journal of Applied Business and Economics. http://www.na-businesspress.com/JABE/Jabe105/AndersonWeb.pdf; retrieved 25 Jan 2017, at 2:56AM IST.

[9] https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11 for coal to CO2 conversion.

[10] https://eosweb.larc.nasa.gov/sse/ for solar irradiance data.

[11]http://bangalore.citizenmatters.in/articles/4648-bescoms-power-sources

