ISSN 2250-3153

# Effect of Grid Connected P.V Power Plant on Electricity Market

**MUHAMMAD SHAHID[1], SWEETY SHARMA[2] and DHARAM NIWAS[3]**

[1] Prof., Al-falah School of Engineering & Technology, Dhauj, Faridabad
monis.shahid@gmail.com
[2] M.Tech.(2nd Year),Al-falah School of Engineering & Technology, Dhauj, Faridabad
Sweetys.1000@yahoo.co.in
[3] Assistant Prof., Indus Institute of Engineering & Technology Kinana, Jind
er.dnyadav@gmail.com

**Abstract:** This paper examines the key determinants that foster the adoption of photovoltaic (PV) power supply systems. The authors provide empirical evidence which suggest that 'government initiatives' and institutional 'finance' are important influencers of the decision to adopt PV power supply systems in developing countries. In order to diffuse PV technology it is also necessary to provide decision-makers with opportunities for direct and vicarious experience of PV systems through 'demonstration sites'. These factors have been ignored in earlier models of the innovation–decision process formulated by Rogers and the new innovation-decision framework proposed by Kaplan. Governments need to play a leadership role, and this coupled with the availability of Finance and Demonstration Sites will result in an increased interest leading to the adoption of PV technology in India. This research has led to the identification of variables such as the government initiatives, demonstration sites and finance, which are critical to the adoption of PV systems in developing countries like India. The research provided empirical evidence that is currently lacking in the area of adoption of PV technology in developing countries. About 72 million households in rural India do not have access to electricity and rely primarily on traditional bio fuels. This research investigates how rural electrification could be achieved in India using different energy sources and what the effects for climate change mitigation could be. We use the Regional Energy Model (REM) to develop scenarios for rural electrification for the period 2005–2030 and to assess the effects on greenhouse gas emissions, primary energy use and costs.

***Index Terms:*** Theoretical consideration, Sampling and data collection**,** concerning rural electrification, Methodology, Modelling rural India, Potential of solar thermal power in India, Natural or Non-renewable energy resources

## I. Introduction

Globally, we are entering a period of commercial acceptance of energy from alternate sources. The visible change has been in the shift in the world energy markets. Renewable energy technologies offer alternatives to fossil fuel use, which not only has constraints in terms of resource availability but is also accompanied by environmental deterioration. Renewable energy technologies are increasingly recognized as one of the central pillars in the development of a sustainable energy strategy. Wind, biomass and solar are the three promising renewable energy technologies. Among these renewable energy sources, solar energy has enormous potential for alleviating dependence on oil and contributing to a sustainable development process [1–4]. Solar radiation striking the Earth is 175,000 TW (1 TW ¼ 1 million watt). Of this, 49% is absorbed and re-radiated or reflected back to space by the atmosphere, 4% is back-scattered from the ground and 47% is absorbed by the earth's surface [5]. We compare the business-as-usual scenario (BAU) with different electrification scenarios based on electricity from renewable energy, diesel and the grid. Our results indicate that diesel systems tend to have the highest CO2 emissions, followed by grid systems. Rural electrification with primarily renewable energy-based end users could save up to 99% of total CO2 emissions and 35% of primary energy use in 2030 compared to BAU. Our research indicates that electrification with decentralized diesel systems is likely to be the most expensive option.

The total commercial energy used for all human activities in the world is less than 15 TW. A major part of the Sun's energy can clearly be tapped into solar power.

## II. THEORETICAL CONSIDERATIONS

Photovoltaic's (PVs) have attracted increased attention in the recent years. Since 1954, PV technology has progressed in leaps and bounds. Improvements in efficiency, progressive reductions in cost and increasingly high reliability have contributed to the expansion of PV globally [6]. The factors which influence the adoption of PV systems in India were identified from an extensive review of existing literature. The study traced the origin of the various models of the adoption/diffusion process to the AIDA model which was first proposed in the early part of the 20th century. After examination of various models, this research is built on the innovation–decision process formulated by Rogers [7]. According to Rogers, knowledge leads to persuasion or interest, and this is followed by the decision to either adopt or reject the innovation. Kaplan [8] expanded the scope of Rogers' model by introducing constructs such as motivation, context, experience and familiarity. Kaplan has proposed in his new innovation–decision framework that motivation and context precede knowledge. He also showed that knowledge is the product of motivation and experience, while familiarity is the product of experience and knowledge. In Kaplan's model, motivation and context are the independent variables, while knowledge, experience and familiarity are intervening variables. The dependent variable in Kaplan's model is interest. The effect of other independent variables such as government initiatives and demonstration sites on experience, knowledge and interest has not been studied in relation to the diffusion of solar-based technology in a developing country like India. Finance is another intervening variable which has been ignored in past studies. Government initiatives, demonstration sites and the availability of finance are important factors which foster the adoption of PV-based power supply systems in developing countries like India [9]. The objective of this paper is to give an overview of the results of the descriptive analysis of the key determinants that influence the adoption of PV-based power supply systems in the hospitality industry in India. These variables include those that have been hitherto R. Peter et al. / Renewable Energy 31 (2006) 2272–2283 2273 ignored in earlier models of the adoption/diffusion process such as Rogers [7] and Kaplan [8].

## III. DATA COLLECTION

### 3.1 Sampling & data collection

The Directory of Hotels and Resorts in India was used as the sampling frame, as it provided a comprehensive listing of the target population. The hotels were categorized according to their star ratings, and adequate care was taken to ensure a representative sample. The sample size is 205. Sampling error and non-sampling errors are two key factors, which affect the overall quality of data [10]. Sampling error is the difference between the result of a sample and the result of a census conducted using identical procedures. It is a statistical fluctuation that occurs because of chance variations in the elements selected for a sample. Sampling errors arise from errors in constructing a sampling frame and selecting a sample. Adequate steps were taken to minimize potential sources of error during the process of data collection. The target population consists of 769 hotels and, as in the case of many industrial products, a census approach was feasible since the target population was not very large. The questionnaires were initially administered to the population through mail surveys. The mail survey was administered across all the elements of the target population. The respondents were requested to mail the completed questionnaires back to the local academic's contact address via the mail-back envelopes that were provided. However, low response rates (3%) necessitated a change to the adoption of administering the questionnaires through trained interviewers. Stratified random sampling was used to ensure that the sample adequately represented the population. More particularly, the proportional stratified random sample was used to ensure that the number of sampling units drawn from each stratum was in proportion to the relative population size of that stratum. The target population comprises of 769 hotels of different star ratings and these are spread across the country. The distribution of these hotels across the four different regions and across the different star ratings are given in Table 1. In order to ensure randomness of the sample drawn, a computer program called 'Research Randomizer' was used to generate random numbers from the list of hotels in the different regions. The distribution of hotels in the sample has been maintained to be the same as the population distribution of hotels across the four different regions in India. In choosing the stratification variable [11] recommends that the elements within the stratum should be as homogeneous as possible, whereas the elements in the different strata should be as heterogeneous as possible. This criterion has been followed and the star rating of the hotels has been used as the stratification variable. Therefore, in selecting the Sample for administering the questionnaires through trained interviewers, the process of stratification and randomization was followed in order to minimize sampling errors. Thus, great care was taken to avoid imbalances in the representativeness of the sample. The data was collected by a prestigious market research firm in India, in six Indian cities spread across the different regions of the country. The sample distribution of hotels across the different star ratings and across the different regions is given in Table 2.

Table 1. Population of hostels

| Hotel | North | South | East | West | All India |
|---|---|---|---|---|---|
| Total number of 4-5 star hotels | 77 | 45 | 17 | 70 | 209 |
| Total number of 3 star hotels | 91 | 74 | 32 | 62 | 259 |
| 1-2 star hotels and Govt. approved hotel | 90 | 82 | 20 | 109 | 301 |
| Total | 258 | 201 | 69 | 241 | 769 |

Table 2. Sample distribution of hostels

| Types of hotel | North (%) | South (%) | East (%) | West (%) | All India (%) |
|---|---|---|---|---|---|
| 4-5 star hotels | 20(37%) | 12(22%) | 4(8%) | 18(33%) | 55(27%) |
| 3-star hotel | 23(35%) | 18(29%) | 8(12%) | 17(26%) | 65(32%) |
| 1-2 star hotel and Govt approved hotels | 25(30%) | 23(27%) | 6(7%) | 31(36%) | 85(41%) |
| Total | 68(34%) | 53(26%) | 18(9%) | 66(32%) | 205(100%) |

### 3.2. Concerning rural electrification

Sinha and Kandpal [12] found already in the 1990s that decentralized renewable energy can be a cost-effective measure for rural electrification in India compared to the grid. Chakrabarti and Chakrabarti [13] elaborate possibilities for rural electrification of remote island communities in India. Nouni et al. [14] explore several options of providing decentralised electricity access to remote areas in India and Bastakoti [15] relates rural electrification to ways of creating energy enterprises. Though energy-related research on India is broad, research on rural electrification and its impacts on climate change mitigation for rural India, as performed in this study, has not been done before.

## IV. GRID CONECTED PV SYSTEM

### 4.1 Block diagram

The basic Grid Connected PV system design has the following components (shows in fig.4.2).

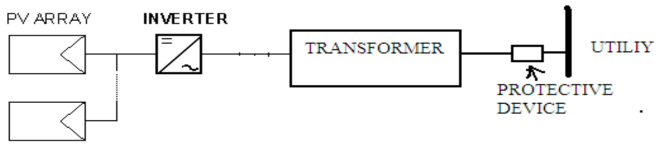


Figure 4.1. Block diagram Grid Connected System

**1. PV array:** A number of PV panels connected in series and/or in parallel giving a DC Output out of the incident irradiance. Orientation and tilt of these panels are important Design parameters, as well as shading from surrounding obstructions.

ISSN 2250-3153

**2. Inverter:** A power converter that 'inverts' the DC power from the panels into AC Power. The characteristics of the output signal should match the voltage, frequency and Power quality limits in the supply network.
**3. Transformer:** A transformer can boost up the ac output voltage from inverter when needed. Otherwise transformer less design is also acceptable.
**4. Load:** Stands for the network connected appliances that are fed from the inverter, or, alternatively, from the grid.
**5. Meters:** They account for the energy being drawn from or fed into the local supply network.
**6. Protective devices:** Some protective devices is also installed, like under voltage relay, circuit breakers etc for resisting power flow from utility to SPV system.
**7. Other devices:** Other devices like dc-dc boost converter, ac filter can also be used for better performance.

### 4.2. Methodology

Modelling with the Regional Energy Model (REM) REM originated from the global energy and GHG emission model ESCAPE4 [16-20]. The ESCAPE model, as well as the slightly adapted REM model, is based on the end-use approach. An end-use function in a certain sector at time t = 0 is taken as a starting point e.g. the function lighting in the residential sector. The useful energy demand (UED) for lighting can be calculated from the amount of kilowatt-hours (kW h) needed for lighting, the fraction (Fr) and the used efficiency (Eff) of the appliances (see Eq. (1)).

$$UED_{t=0} = \sum_{s=1}^{s=n} . \sum_{f=1}^{f=m} ED_{sf_{t=0}} * \sum_{a=1}^{a=K_{sf}} (Fr_a * Eff_a)_{sf} \quad (1)$$

where UED is the useful energy demand; ED, energy demand; Fr, fraction; Eff, efficiency; t, time; s, sector; f, function; a is the appliance. In (1), the total UED for the region or country is calculated for sector (s) for s = 1 to s = n, for function (f) for f = 1 to f = m and for appliance (a) for a = 1 to a = k. The next step is to calculate the UED in the future for time t = t. Several variables can influence this future demand: population at time t (Pop), GDP at time t (GDP) and sector shifts (SAE) as indicated in Eq. (2).

$$UED_t = \sum_{s=1}^{s=n} . \sum_{f=1}^{f=m} UD_{sf_{t=0}} * Pop_t * SAE_{s_t} \quad (2)$$

where UED is the useful energy demand; UE, useful energy; Pop, population at time t; GDP, GDP at time t and SAE, sectoral activity; t, time; s, sector; f, function; a is the appliance. In the last step, the energy demand in time t = t is calculated based on the UED in t = t, the fractions and efficiencies of the appliances in time t = t (see Eq. (3)).

$$TED = \sum_{s=1}^{s=n} . \sum_{f=1}^{f=m} \sum_{a=1}^{a=k_{sf}} (UED * Fr_a / Eff_a)_{sf} \quad (3)$$

where TED is the energy demand at t = 1; UED, useful energy demand; ED, energy demand; Fr, fraction; Eff, efficiency; s, sector; f, function; a is the appliance.

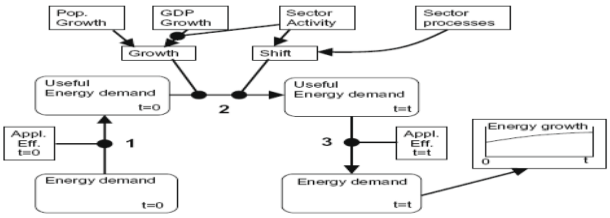


Fig.4.2. Schematic overview of the calculation model in REM.

The above described end-use approach forms the core of the model. Since the model is very flexible, the user can define own sectors (e.g. agriculture, industry, residential, services and transport) and functions (e.g. cooling, cooking, lighting, and space heating). For all sectors, the same functions are defined, but can be used optionally. All appliances present in a certain sector should be placed in one of these defined functions for energy demand. Several appliances per function for a certain sector are allowed. For example, the function lighting in the residential sector of rural India has five types of lamps: kerosene lamps, photovoltaic (PV) lamps, conventional light bulbs, energy-saving light bulbs and Light Emitting Diode (LED) light bulbs. The efficiency of each appliance can increase over time and a sector can shift within a function from one appliance to another, e.g. from mainly kerosene lamps to conventional light bulbs. Besides this sector–function matrix, REM contains a module for the supply side: the energy conversion sector accounting for electricity production, refineries and Combined Heat and Power (CHP). For the supply side, several types of technologies can be defined. The fractions determine how much electricity, heat or oil is generated with a certain technology e.g. wind, coal-fired power plant, district heating, etc.

### 4.3 Modelling rural India

Most energy models assess energy resources, technologies, and emissions. Only few energy models analyse the needs and services related to energy, like the latent energy demand in rural areas in developing countries. This part of the system is hardly modelled, because of its complexity and uncertainty about the underlying processes and assumptions. We however attempt to model the energy needs and services for rural India. With 1.1 billion inhabitants in 2006, India is the second most populous country in the world [21] and is expected to be the world's most populous country in 2050 [22]. In terms of energy, India is the world's fourth highest consumer of energy just after the USA, (the) People's Republic of China and the Russian Federation [23]. India is also one of the world's top five GHG emitters measured in absolute terms. In per capita terms however, an average Indian citizen uses about 15 times less energy than an average US American citizen, emits about 17 times less GHG emissions and uses about 30 times less electricity [21]. In economic terms, India has a steeply increasing GDP growth and an expanding economy. At the same time, India hosts a large population living below poverty line, namely35% of its total population in 2003 [21]. High differences between urban and rural areas prevail. While the Indian economy generates most of its income from services and industries, more than 70% of the total population live in rural areas [22] and depend primarily on non-mechanized agriculture for sustaining their living. Energy poverty is clearly an issue: electrification rates were as low as 50% in rural areas and 62% in total India in 2005.

## V. TEST PROBLEM & RESULT

### 5.1 Introduction

The result of three test problem cases that is IEEE 9 bus case and IEEE 14 bus case are given here.
In 1$^{st}$ case (IEEE9 Bus) describes the two buses that is bus no.5 & 9 each bus contain two case (5MW added, 10MW added).
In 2$^{nd}$ case (IEEE 14 Bus) describes the two buses that is bus no. 2, 3 & 4 each bus contain only single case (5MW added).

### 5.2 Test problem 1 for IEEE 9 bus system

#### 5.2.1 When 5 MW solar Power added at bus no. 5

TABLE 5.1
When 5 MW solar PV Generation added at bus no. 5

ISSN 2250-3153

| Solar power (MW) | Saving conventional energy I ($/hr) | Saving losses (Losses× 𝝀 at ref. bus) in ($/hr) | Amount Receive by solar from load (capacity×𝝀 at bus) in ($/hr) | Net contribution of solar Generation in ($/hr) | Net contribution of solar Generation in (Rs/KWhr) | Reduction in SG subsidy (16-contribution of solar)in (Rs./KWhr) | Net Reduction in Govt. subsidy (12-SG)/ KWhr |
|---|---|---|---|---|---|---|---|
| 1 | 99.84 | 2.56 | 99.674 | 202.47 | 9.31 | 5.69 | 6.31 |
| 2 | 200.35 | 5.7 | 198.708 | 404.76 | 9.309 | 5.69 | 6.31 |
| 3 | 298.55 | 8.54 | 297.10 | 604.19 | 9.264 | 5.74 | 6.26 |
| 4 | 397.42 | 11.35 | 394.86 | 803.63 | 9.241 | 5.76 | 6.24 |
| 5 | 495.98 | 14.04 | 491.96 | 1002.0 | 9.218 | 5.78 | 6.22 |

I. Fig.5.1 shows the variation in Lambda/marginal price (λ) at all buses with 5MW solar power generation at bus no.5, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.5.2 shows the variation of marginal price (λ) with variation of 5MW solar power generation at bus no.5, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III Fig.5.3 shows the variation of reduction in subsidy with variation in 5 MW solar power Generation added at bus no.5, in this case approximately half subsidy will be provide from real subsidy because solar generation approximately more to half generation.

Without solar power added

With solar power added

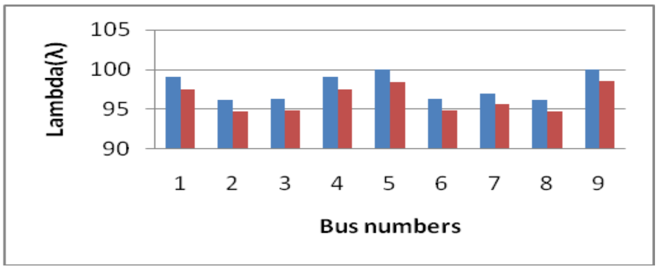


Fig.5.1 5MW PV plant added to bus no. 5

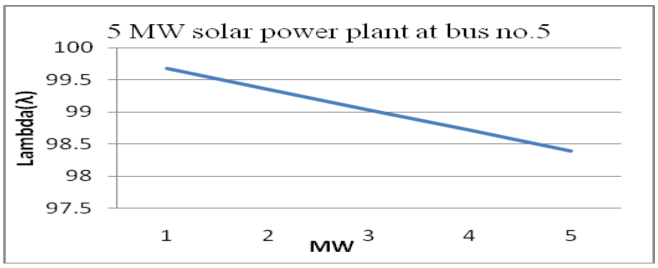


Fig.5.2 5 MW solar plant added at bus no. 5 then variation in Marginal Price (λ)

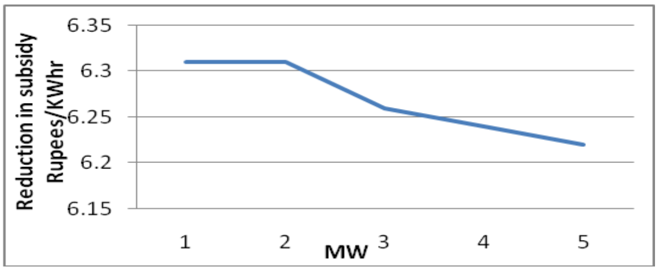


Fig.5.3. 5MW solar plant added at bus no. 5 then variation of reduction in Subsidy

In this case the value of marginal price (λ) can be decrease at all buses and also decrease at 5 different cases when 1MW to 5 MW solar power added to bus no.5. When 1MW to 5MW solar power added at same bus then the reduction in subsidy are 5-6 Rs/KWhr and approximately 40-50% subsidy in 9 bus system case.

### 5.2.2 When 10 MW solar Power added at bus no. 5

TABLE 5.2

When 10 MW solar PV Generation added at bus no. 5

| Solar power (MW) | Saving conventional energy I ($/hr) | Saving losses (Losses×𝝀 at ref. bus) in ($/hr) | Amount Receive by solar from load (capacity ×𝝀 at bus) in ($/hr) | Net contribution of solar Generation in ($/hr) | Net contribution of solar Generation in (Rs/KWhr) | Reduction in subsidy (16-contribution of solar)in (Rs./KWhr) | Net Reduction in Govt. subsidy (12-SG)/KWhr |
|---|---|---|---|---|---|---|---|
| 2 | 199.34 | 5.71 | 198.70 | 403.75 | 9.29 | 5.71 | 6.29 |
| 4 | 397.42 | 11.34 | 394.86 | 803.62 | 9.24 | 5.76 | 6.24 |
| 6 | 594.21 | 16.63 | 588.46 | 1199.30 | 9.20 | 5.80 | 6.20 |
| 6 | 789.73 | 21.84 | 779.52 | 1591.09 | 9.15 | 5.85 | 6.15 |
| 10 | 983.97 | 26.89 | 968.04 | 1978.90 | 9.10 | 5.90 | 6.10 |

I Fig.5.4 shows the variation in Lambda/marginal price (λ) at all buses with 10MW solar power generation at bus no.5, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.5.5 shows the variation of marginal price (λ) with variation of 10MW solar power generation at bus no.5, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III. Fig.5.6 shows the variation of reduction in subsidy with variation in 10MW solar power Generation added at bus no.5, in this case approximately half subsidy will be provide from real subsidy because solar generation approximately more to half generation.

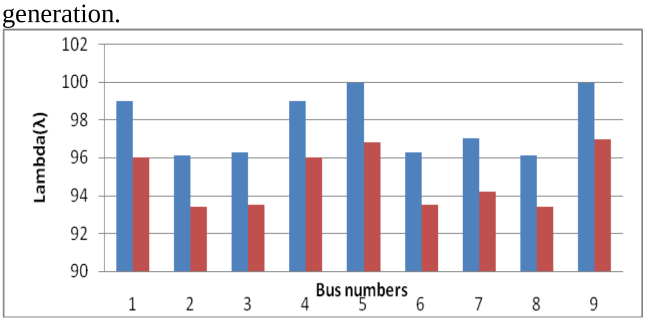


Fig.5.4. 10MW PV plant added to bus no. 5

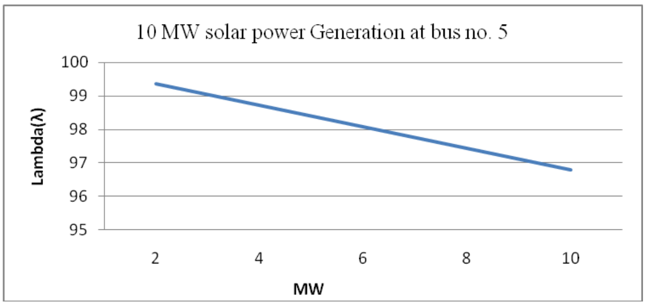


Fig.5.5. 10MW solar plant added at bus no. 5 then variation in Marginal Price (λ)

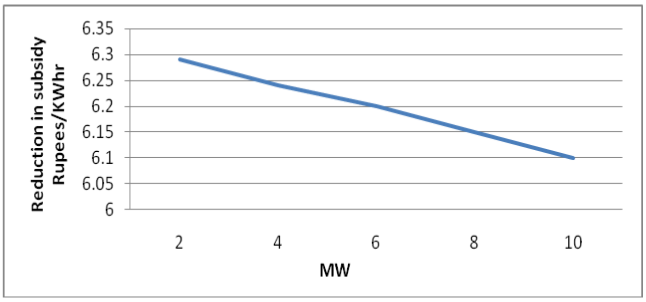


Fig.5.6. 10MW solar plants added at bus no. 5 then variation of reduction in Subsidy

In this case the similarly to above 5 bus case the value of marginal price (λ) can be decrease at all buses and also decrease at 5 different cases when 2MW to 10 MW solar power added to bus no.5. When 2MW to 10MW solar power added at same bus then the reduction in subsidy are 5-6 Rs/KWhr and approximately 40-50% subsidy in 9 bus system case.

### 5.2.3 When 5 MW solar Power added at bus no. 9

TABLE 5.3

When 5 MW solar PV Generation added at bus no. 9

| Solar power (MW) | Saving conventional energy I ($/hr) | Saving losses (Losses ×λ at ref. bus) in ($/hr) | Amount Receive by solar from load (capacity×λ at bus) in ($/hr) | Net contribution of solar Generation in ($/hr) | Net contribution of solar Generation in (Rs/KWhr) | Reduction in subsidy(16-contribution of solar)in (Rs./KWhr) | Net Reduction in Govt. subsidy (12-SG)/KWhr |
|---|---|---|---|---|---|---|---|
| 1 | 99.84 | 2.96 | 99.679 | 202.48 | 9.31 | 5.69 | 6.31 |
| 2 | 199.36 | 5.80 | 199.4 | 404.56 | 9.30 | 5.70 | 6.30 |
| 3 | 298.57 | 8.54 | 297.15 | 604.16 | 9.26 | 5.74 | 6.26 |
| 4 | 397.46 | 11.35 | 394.95 | 803.76 | 9.24 | 5.76 | 6.24 |
| 5 | 496.04 | 14.04 | 492.12 | 1002.2 | 9.22 | 5.78 | 6.22 |

I. Fig.5.7 shows the variation in Lambda/marginal price (λ) at all buses with 5MW solar power generation at bus no.9, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.5.8 shows the variation of marginal price (λ) with variation of 5MW solar power generation at bus no.9, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III. Fig.5.9 shows the variation of reduction in subsidy with variation in 5 MW solar power Generation added at bus no.9, in this case approximately half subsidy will be provide from real subsidy because solar generation approximately more to half generation.

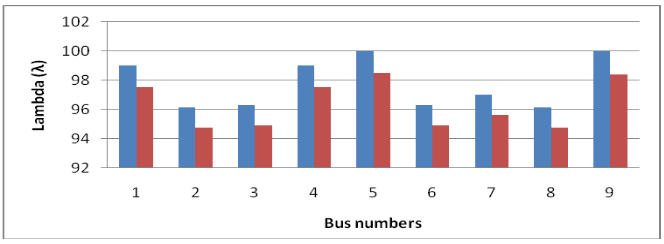


Fig.5.7. 5 MW PV plant added to bus no. 9

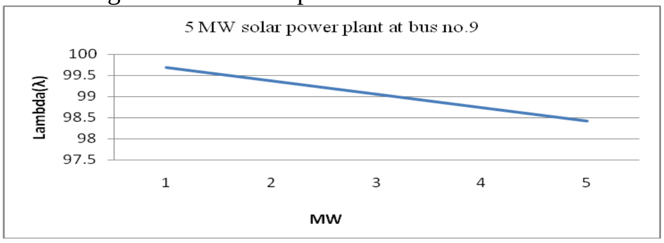


Fig.5.8. 5MW solar plants added at bus no. 9 then variation in Marginal Price (λ)

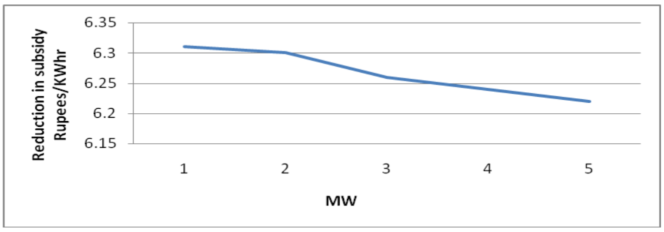


Fig.5.9. 5MW solar plants added at bus no. 9 then variation of reduction in subsidy

In this case the value of marginal price (λ) can be decrease at all buses and also decrease at 5 different cases when 1MW to 5MW solar power added to bus no.9. When 1MW to 5MW solar power added at same bus then the reduction in subsidy are 5.5-6.5 Rs/KWhr and approximately 45-55% subsidy in 9 bus system case.

### 5.2.4 When 10MW solar Power added at bus no. 9

TABLE 5.4

When 10 MW solar PV Generation added at bus no. 9

| SOLAR POWER (MW) | SAVING CONVENTIONAL ENERGY I ($/HR) | SAVING LOSSES (LOSSES× λ AT REF. BUS) IN ($/HR) | AMOUNT RECEIVE BY SOLAR FROM LOAD (CAPACITY×λ AT BUS) IN ($/HR) | NET CONTRIBUTION OF SOLAR GENERATION IN ($/HR) | NET CONTRIBUTION OF SOLAR GENERATION IN (RS/KWHR) | REDUCTION IN SUBSIDY(16-CONTRIBUTION OF SOLAR) IN (RS./KWHR) | NET REDUCTION IN GOVT. SUBSIDY(12-SG)/KWHR |
|---|---|---|---|---|---|---|---|
| 2 | 199.36 | 5.81 | 18.73 | 403.90 | 9.29 | 5.71 | 6.29 |
| 4 | 397.46 | 11.35 | 394.95 | 803.76 | 9.24 | 5.76 | 6.24 |
| 6 | 594.31 | 16.72 | 588.65 | 1199.68 | 9.20 | 5.80 | 6.20 |
| 8 | 789.90 | 22.02 | 779.86 | 1591.78 | 9.15 | 5.85 | 6.15 |
| 10 | 984.24 | 27.07 | 968.57 | 1979.88 | 9.10 | 5.90 | 6.10 |

I. Fig.5.10 shows the variation in Lambda/marginal price (λ) at all buses with 10MW solar power generation at bus no.9, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.5.11 shows the variation of marginal price (λ) with variation of 10MW solar power generation at bus no.9, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III. Fig.5.12 shows the variation of reduction in subsidy with variation in 10 MW solar power Generation added at bus no.9, in this case approximately half subsidy will be provide from real subsidy because solar generation approximately more to half generation.

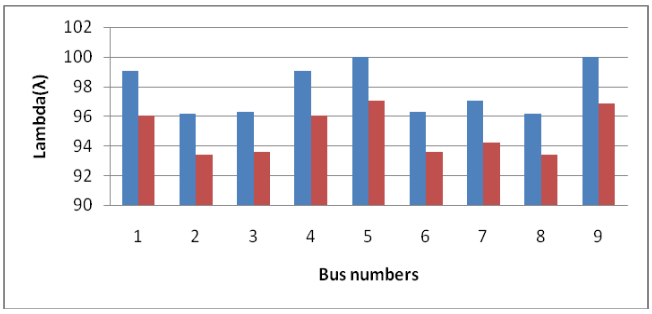


Fig.5.10. 10MW PV plant added to bus no. 9

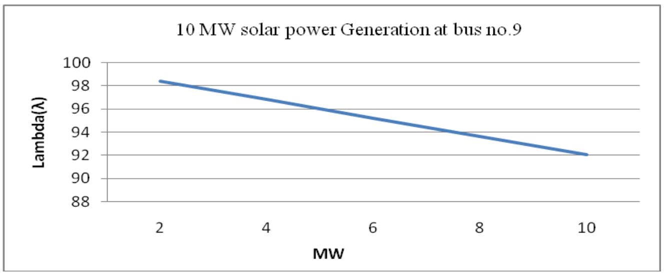


Fig.5.11. 10MW solar plants added at bus no. 9 then variation in Marginal Price (λ)

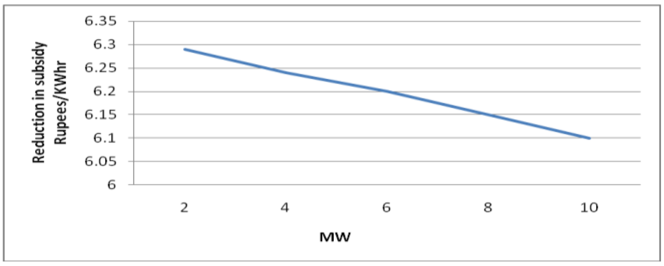


Fig.5.12. 10MW solar plants added at bus no. 9 then variation of reduction in Subsidy

In this case similarly to above 9 bus case the value of marginal price (λ) can be decrease on all buses and also decrease at 5 different cases when 2MW to 10MW solar power added to bus no.9. When 2MW to 10MW solar power added at same bus then the reduction in subsidy are 5.5-6.5 Rs/KWhr and approximately 45-55% subsidy in 9 bus system case.

### 5.3 Test problem 2 for IEEE 14 bus system

#### 5.3.1 When 5MW solar Power added at bus no. 2

TABLE 5.5

When 5 MW solar PV Generation added at bus no. 2

| Solar po | Saving conventional | Saving losses (Losses | Amount Receiv | Net contribution of | Net contribution | Reduction in | Net Reduction |
|---|---|---|---|---|---|---|---|

| wer (MW) | energy I ($/hr) | ×λ at ref. bus) in ($/hr) | e by solar from load (capacity×λ at bus) in ($/hr) | solar Generation in ($/hr) | of solar Generation in (Rs/KWhr) | subsidy(16-contribution of solar)in (Rs./KWhr) | in Govt. subsidy (12-SG)/KWhr |
|---|---|---|---|---|---|---|---|
| 1 | 153.41 | -4.84 | 153.36 | 301.935 | 13.89 | 1.11 | 10.89 |
| 2 | 306.73 | -9.687 | 306.58 | 603.623 | 13.88 | 1.12 | 10.88 |
| 3 | 460.00 | -14.52 | 456.65 | 902.13 | 13.83 | 1.17 | 10.87 |
| 4 | 631.17 | -19.36 | 612.57 | 1224.38 | 14.00 | 0.92 | 11.08 |
| 5 | 766.27 | 24.19 | 765.35 | 1507.43 | 13.86 | 1.14 | 10.86 |

I. Fig.7.13 shows the variation in Lambda/marginal price (λ) at all buses with 5MW solar power generation at bus no.2, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.7.14 shows the variation of marginal price (λ) with variation of 5MW solar power generation at bus no.2, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III. Fig.7.15 show the variation of reduction in subsidy with variation in 5 MW solar power Generation added at bus no.2 in this case very less subsidy will be provide because contribution of solar power approximately equal to actual solar generation.

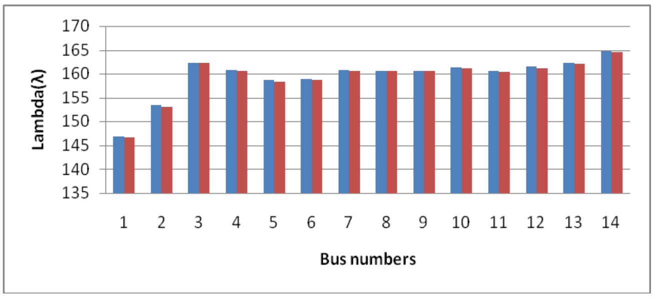


Fig.5.13. 5MW PV plant added to bus no. 2

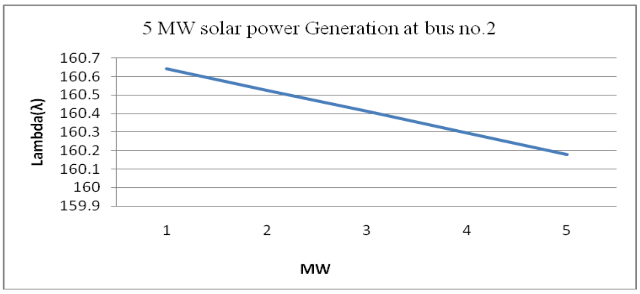


Fig.5.14, 5MW solar plants added at bus no. 2 then variation in Marginal Price (λ)

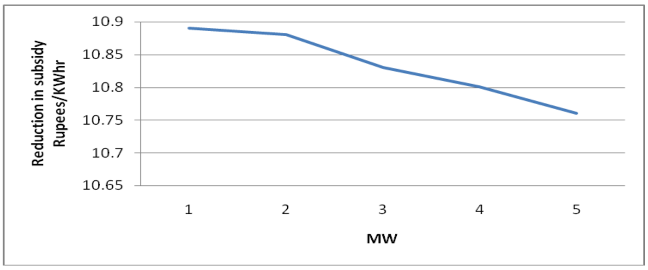


Fig.5.15, 5MW solar plants added at bus no. 2 then variation of reduction in Subsidy

In this case the value of marginal price (λ) can be decrease at all buses and also decrease in large amount compare to 9 bus system on all buses and also decrease at 5 different case when 1MW to 5MW solar power added to bus no.2. When 1MW to 5MW solar power added at same bus then the reduction in subsidy are 9-10 Rs/KWhr and approximately 75-85% subsidy in 14 bus system case.

### 5.3.2 When 5MW solar Power added at bus no. 3

TABLE 5.6

When 5 MW solar PV Generation added at bus no. 3

| Solar power (MW) | Saving conventional energy I ($/hr) | Saving losses (Losses ×λ at ref. bus) in ($/hr) | Amount Receive by solar from load (capacity×λ at bus) in ($/hr) | Net contribution of solar Generation in ($/hr) | Net contribution of solar Generation in (Rs/KWhr) | Reduction in subsidy (16-contribution of solar)in (Rs./KWhr) | Net Reduction in Govt. subsidy (12-SG)/KWhr |
|---|---|---|---|---|---|---|---|
| 1 | 162.28 | 1.32 | 162.244 | 325.84 | 14.99 | 0.01 | 11.99 |
| 2 | 324.49 | 2.64 | 324.3 | 651.43 | 14.98 | 0.02 | 11.98 |
| 3 | 486.65 | 4.11 | 486.40 | 977.16 | 14.98 | 0.02 | 11.98 |
| 4 | 648.76 | 5.43 | 648.31 | 1302.50 | 14.97 | 0.03 | 11.97 |
| 5 | 810.81 | 6.75 | 810.10 | 1624.66 | 14.94 | 0.06 | 11.94 |

**I.** Fig.5.16 shows the variation in Lambda/marginal price (λ) at all buses with 5MW solar power generation at bus no.3, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.

II. Fig.5.17 shows the variation of marginal price (λ) with variation of 5MW solar power generation at bus no.3, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.

III. Fig.5.18 shows the variation of reduction in subsidy with variation in 5 MW solar power Generation added at bus no.3, in this case very less subsidy will be provide because contribution of solar power approximately equal to actual solar generation.

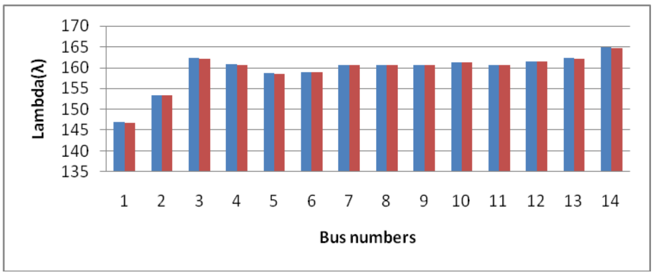


Fig.5.16. 5MW PV plant added to bus no. 3

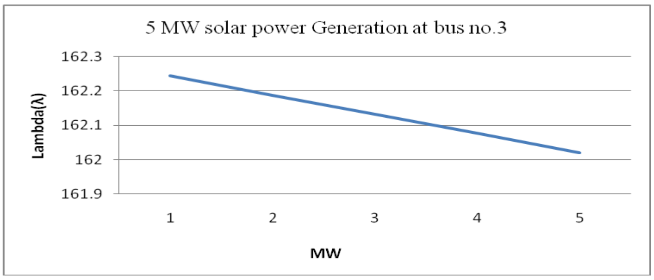


Fig.5.17. 5MW solar plants added at bus no. 3 then variation in Marginal Price (λ)

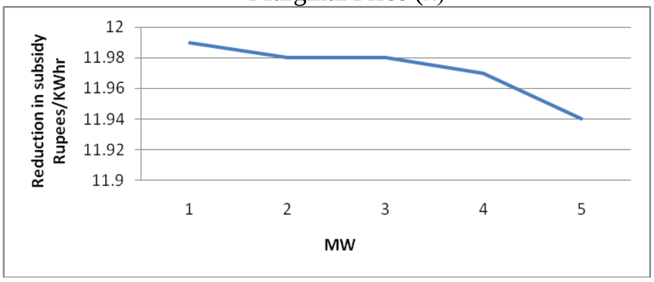


Fig.5.18. 5MW solar plants added at bus no. 3 then variation of reduction in Subsidy

In this case similarly to above 2 bus case the value of marginal price (λ) can be decrease in large amount compare to 9 bus system on all buses and also decrease at 5 different case when 1MW to 5MW solar power added to bus no.3. When 1MW to 5MW solar power added at same bus then the reduction in subsidy are 10-11 Rs/KWhr and approximately 80-90% subsidy in 14 bus system case.

### 5.3.3 When 5MW solar Power added at bus no. 4

TABLE 5.7

When 5 MW solar PV Generation added at bus no. 4

| Solar power (MW) | Saving conventional energy I ($/hr) | Saving losses (Losses×λ at ref. bus) in ($/hr) | Amount Receive by solar from load (capacity×λ at bus) in ($/hr) | Net contribution of solar Generation in ($/hr) | Net contribution of solar Generation in (Rs/KWhr) | Reduction in subsidy (16-contribution of solar)in (Rs./KWhr) | Net Reduction in Govt. subsidy (12-SG)/KWhr |
|---|---|---|---|---|---|---|---|
| 1 | 160.74 | 1.03 | 160.702 | 322.47 | 14.83 | 0.17 | 11.83 |
| 2 | 321.41 | 2.05 | 321.29 | 644.75 | 14.83 | 0.17 | 11.83 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3 | 482.02 | 3.08 | 481.76 | 966.86 | 14.82 | 0.18 | 11.82 |
| 4 | 642.58 | 4.10 | 642.10 | 1288.78 | 14.82 | 0.18 | 11.82 |
| 5 | 803.08 | 5.14 | 802.345 | 1610.56 | 14.81 | 0.19 | 11.81 |

I. Fig.5.19 shows the variation in Lambda/marginal price (λ) at all buses with 5MW solar power generation at bus no.4, when the capacity of solar power increase at the bus then the subsidy can be gradually decrease.
II. Fig.5.20 shows the variation of marginal price (λ) with variation of 5MW solar power generation at bus no.4, variation in marginal price can be decrease when in the capacity of solar power increase at the bus.
III. Fig.5.21 shows the variation of reduction in subsidy with variation in 5 MW solar power Generation added at bus no.4, in this case very less subsidy will be provide because contribution of solar power approximately equal to actual solar generation.

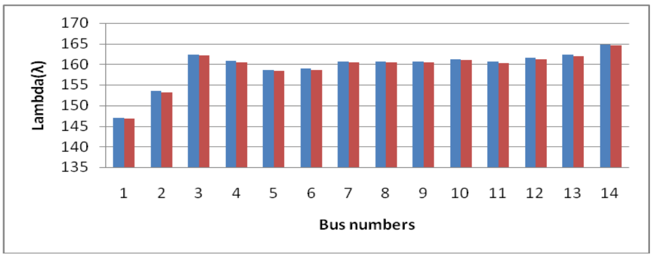


Fig.5.19. 5MW PV plant added to bus no. 4

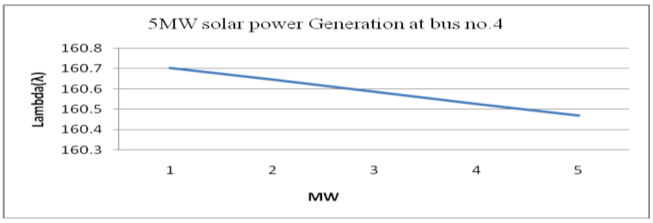


Fig.5.20. 5MW solar plants added at bus no. 4 then variation in Marginal Price (λ)

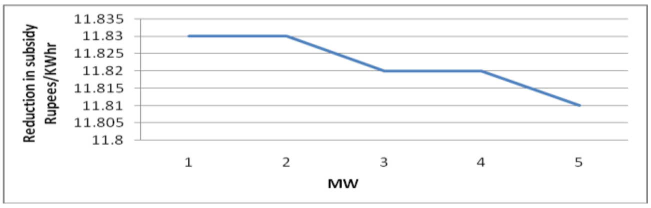


Fig.5.21. 5MW solar plants added at bus no. 4 then variation of reduction in Subsidy

In this case similarly to above 3 bus case the value of marginal price (λ) can be decrease in large amount compare to 9 bus system on all buses and also decrease at 5 different case when 1MW to 5MW solar power added to bus no.4. When 1MW to 5MW solar power added at same bus then the reduction in subsidy are 10-11 Rs/KWhr and approximately 80-90% subsidy in 14 bus system case.

## VI. CONCLUSION & FUTURE SCOPE OF WORK

This thesis presents current status, major achievements and important aspects of solar energy in India and implementing solar for the future is also been presented. Solar energy is expected to play a very significant role in the future especially in developing countries, but it has also potential prospects for developed countries.
This dissertation consists of an effective Study for the Solar cell, Solar Photovoltaic Technology, Grid connected Photovoltaic plant, solar power Status in India & Global, Solar energy Tariff & Policy and find the Marginal price (λ) using optimal power plow programming with the help of MATLAB. This research work deals with, work on reduction in subsidy for solar power plant in deferent IEEE bus system ( IEEE9, IEEE14,) using optimal power flow program. Solar power plant added at load bus then calculate the outcome of reduction in subsidy. The studies had been carried out reduction in subsidy in order to improve the solar generation, minimize the loss in the system. The subsidy provide by government is gradually decrease when the solar power added to different buses in IEEE9, IEEE14, bus system.
When solar power added at bus no.5 in IEEE 9 bus system then the reduction in subsidy can be decrease approximately 40% and the similar process has follow to IEEE 14 bus system then the reduction in subsidy approximately 70%. But these process applying for IEEE 30 bus system then the reducing in subsidy is very small approximately 10% of total subsidy given by the Government. When the comparing of subsidy of these three IEEE bus then the outcome is that the reduction in subsidy can be more when solar power generation added the IEEE14 bus system.
In future, when efficiency of the solar cell and Generation of solar power can be increase then the cost of solar power generation gradually decrease. In other way the solar power generation added at different IEEE bus system them we can measure the reduction in cost from solar power generation and reduction in subsidy for solar power generation in future.
.

## REFERENCES

[1] Carmody ER, Sarkar AU. Solar box cookers: towards a decentralized sustainable energy strategy for Sub-Saharan Africa. Renew Sustain Energy Rev 1997; 1(4):291–301.
[2] Garg HP, Krishnan CP. The burning question-energy in the new millennium. IREDA News 1999; 10(4):17–21.
[3] Oliver M, Jackson T. The market for solar photovoltaic. Energy Policy 1999; 27(7):371–85.
[4] Rajagopal S. Renewable energy for rural development. IREDA News 1999;10(4):37–43.
[5] Islam S, Huda AU. Proper utilization of solar energy in Bangladesh: effect on the environment, food supply and the standard of living. Renew Energy 1999;17(2):255–63.
[6] Sayigh A. Renewable energy—the way forward. Appl Energy 1999;64(1–4):15–30.
[7] Rogers EM. Diffusion of innovations, 4th ed. New York: Free Press; 1995.
[8] Kaplan AW. From passive to active about solar electricity: innovation decision process and photovoltaic interest generation. Technovation 1999;19(8):467–81.
[9] Peter R, Nayar CV. Conceptual model for marketing solar based technology to developing countries. Renew Energy 2002;25(4):511–24.
[10] Malhotra NK. Marketing research an applied orientation, 4th ed. NJ: Prentice Hall; 2003.
[11] Zikmund WG. Exploring marketing research, 7th ed. Fort Worth: Harcourt College Publishers; 2000.
[12] Sinha CSM, Kandpal TC. Decentralized versus grid electricity for rural India: the economic factors. Energy Policy 1991;19(5):441–8.

[13] Chakrabarti S, Chakrabarti S. Rural electrification programme with solar energy in remote region – a case study in an island. Energy Policy 2002;30(1): 33–42.
[14] Nouni MR, Mullick SC, Kandpal TC. Providing electricity access to remote areas in India: an approach towards identifying potential areas for decentralized electricity supply. Renew Sust Energ Rev 2008;12(5):1187–220.
[15] Bastakoti BP. Rural electrification and efforts to create enterprises for the effective use of power. Appl Energy 2003;76(1–3):145–55.
[16] CEC, DG XI. Development of a framework for the evaluation of policy options to deal with the greenhouse effect. A scientific description of the ESCAPE model: version I.I. CEC: Brussels; 1992.
[17] Hulme M, Raper SCB, Wrigley TML. An integrated framework to address climate change (ESCAPE) and further developments of the global and regional climate modules (MAGICC). Energy Policy 1995;23(4/5):347–55.
[18] Hulme M. A scientific description of the ESCAPE software. Norwich: Climatic Research Unit; 1992.
[19] Hulme M. A user manual for the ESCAPE software. Norwich Climatic Research Unit; 1992.
[20] Rotmans J, Hulme M, Downing TE. Climate change implications for Europe. An application of the ESCAPE model. Global Environ Change 1994; pag. 97–124.
[21] World Bank. World Development Indicators. Data query; 2008. <http:// www.ddp-ext.worldbank.org/ext/DDPQQ/member.do?method=getMembers&userid=1&queryId=135> [accessed 16.05.08].
[22] UN PRB. 2006 World population data sheet. Washington: United Nations´Population Reference Bureau; 2006.
[23] IEA. Energy statistics: online data service; 2008. <http://www.data.iea.org/ ieastore/statslisting.asp> [accessed 21.05.08].
[24] World Bank. World Development Report 1998/99. Washington: Oxford University Press, 1999.
[25] Bansal NK, Minke G. Climate zones and rural housing in India. JuÈ lich: Kernforschungsanlage,1988.
[26] Development Alternatives. Wasteland Development, New Delhi, 1994.
[27] National Association of Regulatory Utility Commissioners, (NARUC) 1991. Electric Power Technology. Options for Utility Generation and Storage, Staff Paper, Technology Subcommittee, Finance and Technology Committee, February.
[28] Hohmeyer O. The solar costs of electricity—renewable versus fossil and nuclear energy. Solar Energy 1992;11:231–50.
[29] Cline WR. The economics of global warming. Washington, DC: Institute of International Economics; 1992.

## AUTHORS

Muhammad Shahid passed his B.E. in Electrical Engineering 1995 from Jamia Millia Islamia New Delhi & M.Tech. degree in Power Systems in Department of Electrical & Electronics Engineering from Al-Falah School of Engineering & Technology affiliated to Maharshi Dayanand University, Rohtak (Haryana), India, in 2012. . He has a 14 yrs industrial experience & 3 years teaching experience. Presently he is an Assistant Professor in Al-Falah School of Engineering & Technology , Dhauj, Faridabad (Haryana), India.

Sweety Sharma received his B.Tech. degree in Electrical & Electronics Engineering from Jind institute of engineering & technology, Jind affiliated to Kurukshetra University, Kurukshetra (Haryana), India in 2009, and now Pursuing M.Tech. degree in Electrical Engineering with specialization in power system from Al - Falah School of Engineering & Technology affiliated to Maharshi Dayanand University, Rohtak (Haryana), India.

Dharamniwas received his B.Tech. degree in Electrical Engineering from Hindu College of Engineering, Sonipat affiliated to Maharishi Dayanand University, Rohtak (Haryana), India in 2009,and M.Tech. degree in Electrical Engineering with specialization in power System from Al-Falah School of Engineering & Technology affiliated to Maharshi Dayanand University, Rohtak (Haryana), India, in 2012. He has 4 years teaching experience. Presently he is an Assistant Professor in Indus Institute of Engineering & Technology Kinana, Jind (Haryana) India.