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Renewable Energy Technology Diffusion to Mitigate Climate Change Impact

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Abstract
Diffusion of Renewable Energy Technologies (RETs) is governed by the status of the technology in terms of efficiency and techno-economical feasibility. The states plans for the deployment of resources for development, with special reference to sustainable environment and the demand and supply energy model help to provide more focus on the long term goals. The theory of diffusion modeling allows analysis of diffusion processes and the study of growth rates of different technologies, particularly for India with the eight National Missions under the National Action Plan for Climate Change (NAPCC).

The paper presents energy computing models for optimally allocating different types of renewables in the distribution system so as to minimize energy loss. The proposed energy computing model optimises the integration of renewable energy resources with technical and financial feasibility. An econometric model identifies the potential of renewable energy sources, mapping them for computational analysis, which enables the study to forecast the demand and supply scenario. The enriched database on renewable sources and Government policies customise the delivery model for potential to transcend the costs vs. benefits barrier. The simulation and modeling techniques have overtaken the drawbacks of traditional information and communication technology (ICT) in tackling the new challenges in maximizing the benefits with smart hybrid grid. Data management has to start at the initial reception of the energy source data, reviewing it for events that should trigger alarms into outage management systems and other real-time systems such as portfolio management of a virtual hybrid power plant operator. The paper highlights two renewable source, solar and wind, for study, which can be extended to other renewable sources.

Key words: Techno-Economical feasibility, RET diffusion model, Energy Efficiency, PAT, Renewable Energy Certificates

Introduction

Recognizing that climate change is a global challenge, India will engage actively in multilateral negotiations in the UN Framework Convention on Climate Change, in a positive, constructive and forward-looking manner. Our objective will be to establish an effective, cooperative and equitable global approach based on the principle of common but differentiated responsibilities and respective capabilities, enshrined in the United Nations Framework Convention on Climate Change (UNFCCC). we must not only promote sustainable production processes, but equally, sustainable lifestyles across the globe

There are Eight National Missions which form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change. While several of these programmes are already part of our current actions, they may need a change in direction, enhancement of scope and effectiveness and accelerated implementation of time-bound plans. In this paper some of initiatives taken are focus of discussion which are primarily necessary for RET diffusion.

Modern electrical power systems (the grid) have been developing since the late 19th century and take different forms around the world. Some systems are very advanced and highly reliable but are at different scales, for example the Eastern Interconnection in the USA that serves 228 million consumers across 8.85 million square kilometers contrasts with smaller, more isolated systems such as Ireland serving a population of 6.2 million across 81,638 km2 (NISRA, 2009). Other systems are not as well developed but are rapidly evolving. This growth of electricity demand coupled with the geographically dispersed nature of many renewable sources makes electricity an attractive energy vector to harness RE where adequate network infrastructure is available. Additionally, with the development of inexpensive and effective communications systems and technologies as well as smart meters, the electrical power system is experiencing dramatic change. All these potential developments—RE, demand side participation, electric vehicles and any new thermal generation (i.e., fossil fuel or nuclear)—need to be integrated into electrical power systems. They collectively and individually pose common and unique challenges. The promotion of renewable energy to mitigate the impact of climate change is described in section 2 and additional Carbon saving by energy efficiency in section 3. The section 4 describe a complete model for RE technology diffusion which ended with section 5 on conclusion.

2 Renewable Energy Certification in India

2.1 *Renewable Energy Potential*

The REC mechanism has the prime objectives of RPO regulation, increased flexibility for participants to carry out RE transactions, overcoming geographical constraints, reduce transaction costs, development of all encompassing incentive mechanism and reduce risks for local distribution licensee.

India has been bestowed with huge RE potential on sources including solar, wind, biomass and small hydro. Central Electricity Authority conducted a survey on energy potential and highlighted India's potential of solar energy approximately at 5000 trillion kWh/year equivalent. The combined potential of various RE sources excluding solar energy, in some major states in India, is shown in figure 1 below [Goyal Mohit , Jha Rakesh, (2009); Strategic Plan (2011]. The states, after considerations on the potential of REC as highlighted in fig.1, have announced promotional benefits for renewable energy. These benefits are in the form of accelerated depreciation benefits, tax benefits, generation based incentives and capital subsidy. Further, CDM benefit is also available to renewable energy projects [Kumar R, Agarwala A.K., (2013-1)].

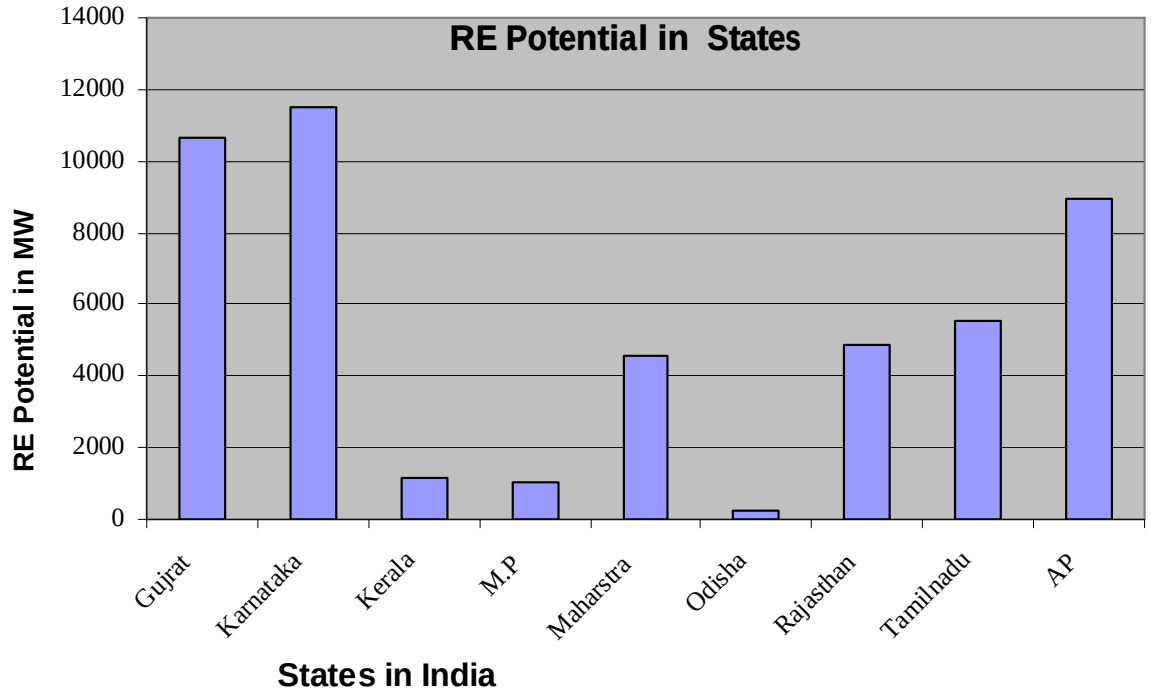

Fig. 1: State-wise Gross RE Potential Capacity(Excluding Solar)

The Solar Mission has set a target of 20,000 MW and stipulates implementation and achievement of the target in 3 phases, with first phase 2012-13, second phase 2013-2017 and the third phase 2017-2022, for various components, including grid connected solar power.

Grid connected Solar Thermal power projects of an aggregate capacity of 500 MW have been selected in FY 2010-11. Solar PV power projects of about 200 MW capacity have been selected in FY 2010-11. Grid Connected Solar PV power projects of up to 350 MW capacity are selected in FY 2011-12.

2.2 *Renewable Energy Certification Mechanism*

In this mechanism, one REC is issued to the RE generator for one MWh electrical energy fed into the grid. The REC issued by SERC has a Unique Certificate Number with information on name of the issuing body, generator identity, type of generation technology, installed capacity of the generator, location of the generator and signature of the authorized person. The REC generator must apply within a period three months of the generation for issuance of RE certificate on grid connected RE projects of 250 kW and above [Kumar R, Agarwala A.K., (2013-1]. The REC is available for trade up to 365 days after the date of issuance.

The RE generator identifies the RE potential and coordinates with state Government for the power sale agreement. The approved RE generator installs the RE plant and contacts state load distribution centre (SLDC) for the supply

of energy to the grid and energy metering. SLDC monitors the energy distribution and certifies the energy fed to the distributor for the issuance of REC by CERC. The REC issued by registry are tradable at two power exchanges within 365 days.

2.3 *Renewable Energy Purchase Obligation*

The Electricity Act 2003 (EA 2003) sets Renewable Purchase Obligation (RPO) targets for distribution companies to purchase a certain percentage of their total power requirement from renewable energy sources [Kumar R, Agarwala A.K., (2013)]. The RE generator may sell electricity to the distribution company and the associated RECs to the distribution company or any other obligated entity. The RE generator may sell RECs to the entities with RPO target in the State or outside the State [RE-2013]. The methodology to identify RPO obligation as given in table 1 depends on the following factors:

- Projections of total quantum of energy required for sale in the State and Central Govt. policies.
- Potential for different types of renewable energy in the State and quantum of energy currently being generated by renewable sources within the State.
- Technical & Commercial impact of renewable power on the retail tariff.

S.N	**State/UT In India**	**RPO (%) 2013-14**		**S.N.**	**State/UT in India**	**RPO (%) 2013-14**
1	Andhra Pradesh	**5.00**		15	Maharashtra	**8.00**
2	Assam	**5.60**		16	Meghalaya	**1.00**
3	Arunachal Pradesh	**5.60**		17	Odisha	**6.00**
4	Bihar	**4.50**		18	Punjab	**3.50**
5	Chattisgarh	**6.25**		19	Rajasthan	**8.20**
6	Delhi	**4.80**		20	Tamil Nadu	**9.00**
7	Gujrat	**7.00**		21	Tripura	**1.00**
8	Haryana	**3.00**		22	Uttrakhand	**5.05**
9	Himachal Pradesh	**10.25**		23	Uttar Pradesh	**6.00**
10	Jammu & Kashmir	**5.00**		24	West Bangal	**4.00**
11	Jharkhand	**4.00**		25	Goa & UTs	**3.00**
12	Karnataka BESCOM,MESCOM, CHESCOM* For other supplier	**10.25 (for >5MW CPP)** **7.25**		26	Manipur	**5.00**
13	Kerala	**3.90**		27	Mizoram	**7.00**
14	Madhya Pradesh	**5.50**		28	Nagaland	**8.00**
Renewable Purchase Obligation on Captive Power Plant and Open Access * BESCOM,MESCOM, CHESCOM are the Electricity supply Company in Karnataka						

Table 1 – Indian States with RPO obligation for the FY 2013-14

2.1 *Renewable Energy Certificate Trading*

The trading of REC is on two exchanges with centralised information and control mechanism at Central Electricity Regulatory Commission (CERC). The REC Trading started in April , 2011 with a slow response but has gained momentum within a few months operated through two exchanges PXIL and IEX. These exchanges offer easy access, transparent and fully electronic market place, and a robust and user friendly platform to trade on RECs. The trading from DEcember, 2011 to June, 2013 is shown in fig 2, reflects that REC certificate issuance growth rate is sharp rise after September, 2012, due to marketing constraint and its streamline around 3,00,000 every month.

The REC issued are rising continuously, while the REC redeemed are stagnated below three lakhs, which create large closing balance. The rise in closing balance indicates the low demand for REC and the cost is likely to fall in future. The REC closing balance on 31st December, 2012 is 14,86,111 and floor trade price for non- solar REC is INR 1500 ($28) and for solar REC is INR 12620 ($ 230).

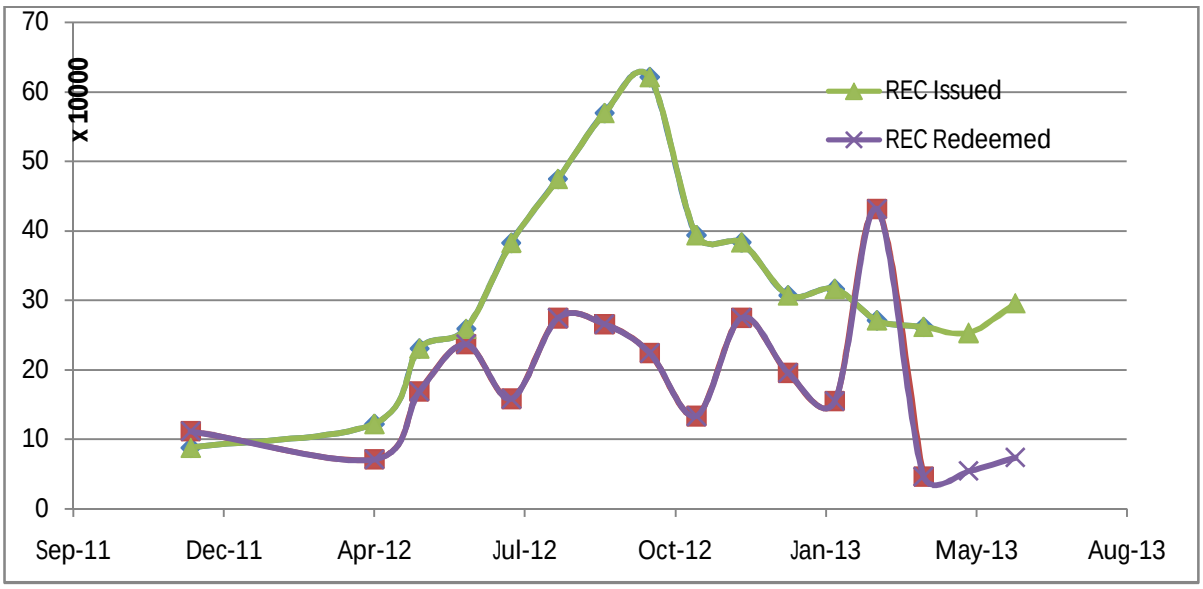

Fig 2; REC status from December, 2011 to June, 2013

3 Perform, Achieve and Trade(PAT)

3.1 Mechanism

To enhance energy efficiency in industries, a new mechanism 'Perform, Achieve and Trade' (PAT) is designed with the basic green energy concept to comply with international policy similar to the Energy Efficiency Portfolio Standard (EEPS) mechanisms in US, Tradable Green certificates (TGC) in Europe and similar programmes in other countries [33]. The PAT mechanism designed to promote enhanced energy efficient technology to be adopted by industry to improve target on specified specific energy consumption (SEC) in a cost-effective manner. Perform Achieve and Trade (PAT) needs improvement to give its operational mechanism scale, complexities, timelines for successful delivery.

Bureau of Energy efficiency (BEE) is the centralised agency for the implementation of PAT programme and will start trade on certificates by 2014. The PAT mechanism targets energy incentive sector, and identified 8 sectors for the first phase 2012-15, namely Thermal Power Plants, Fertilizer, Cement, Pulp and Paper, Textiles, Chlor-Alkali, Iron & Steel and Aluminum. The PAT framework has a methodology for identification of designated consumer (DC) and currently 478 DCs are working with BEE in 8 sectors. The design phase includes calculations for setting up SEC for each DC and reduction target [Kumar R, Agarwala A.K., (2013)] .

3.2 ESCerts Trading

BEE in coordination with Ministry of Power, Ministry of Finance, Ministry of new & Renewable energy and Ministry of Science & Technology prepared a draft design of PAT assessment document (PAD), which contains the information on process and technology upgraded which reflected in the form of enhanced energy saving. This paper proposes ESCerts trading mechanism and methodology that needs extensive information exchange between Designated Consumers (DCs), State Designated Agencies (SDAs), Designated Energy Auditors (DENAs), Power Exchanges, Bureau of Energy Efficiency (BEE) and Central Registry on a regular basis. The central registry office is assigned responsibility for creation of the information network and share timely and accurate information while maintaining confidentiality, transparency and security. This could be achieved through adopting dedicated software programme **PAT-Net**, an online integrated information system for the operation and data management for creation, transfer, trading and cancellation of ESCert. The PAT-Net is an information consortium and provides connection to all the BEE, DCs, SDAs, DENAs, Trading exchanges, Central Registry, trader and banks. Each one of them will be provided with a unique access depending on their category, with user rights assigned accordingly. In the proposed model, PAT-Net, overall administrative control, rights and responsibility entrusted on BEE.

4 Renewable Energy Technology Diffusion Model

In order to achieve the most accurate predictive analysis, influential factors in energy application have been taken into full consideration during design of energy model in this article. Taking the collected abundant data and related economic indicator models through further strict calculation can be used to predict relative economic indicators. Three typical renewable energy sources, namely solar, wind and geothermal energy have been taken in the thesis to explore the design thinking of the energy models.

4.1 Solar Energy Photovoltaic :

The solar energy photovoltaic power model with economic indicators is

$$E_{SPV} \{ I_R, P_V, L, T_{PV}, S_{PV} \} \quad \text{--- (1)}$$

- The global solar radiation I_R obtained from the surface of the solar cell array
- The energy in the form electrical voltage and current produced by solar cell array is P_V
- The inverter loss during conversion to usable energy L
- Substituted quantity T_{PV} of PAT for conventional energy power conversion and smart grid technology
- REC Certificate for the generation S_{pv}

4.2 ***SolarThermal Power :*** The Solar Thermal heating Energy is obtained as;

$$E_{ewh} \{ \varphi, \eta_1, \eta_2, Q_{uf}, T_{ewh}, S_{ewh} \} \quad \text{--- (2)}$$

- Solar energy assurance factor φ
- Solar energy heat collecting system efficiency η_1
- Solar water heating system efficiency η_2
- Useful heat quantity of solar heat collecting system Q_{uf}
- Substituted quantity T_{ewh} of PAT for conventional energy power conversion and smart grid technology
- REC Certificate for the generation S_{pv}

4.3 ***Energy Model for REC, PAT and Fossil fuel Power Plant***

The renewable energy Model is considered for the factor from equation 1, 2, 4 and 6 for the availability of resources in consideration of fossil fuel energy (E_{fs})

$$E_T \{ E_{re} E_{fs} \} \quad \text{where } E_{re} = \{ E_{spv}, E_{ewh} E_w E_{gshp} \ldots E_{other\ re} \} \quad (3)$$

The Bass diffusion model [Rao K. Usha, Kishore V.V.N., (2010)], as considered by K Usha Rao et al. [37] is a mixed influence model with three parameters i.e. coefficient of technology, policy and business innovation, coefficient of imitation and total potential.

$$\frac{dN}{dt} = \left[p + r + Ecert + \frac{q}{m} \{N(t)\} \right] [m - N(t)] \quad (4)$$

where p is the coefficient of technology and business innovation, r is RE certification and ECert carbon mitigation policy, q is the coefficient of imitation and m is the total potential.

The Control Design and Simulation Module provides a numerical simulation environment that enables users to test the model, and the Module can be used to analyse the interactions between hybrid mechanical-electrical systems [Krishnan S S (2010); Rao K. Usha, Kishore V.V.N., (2010)] . Furthermore, the quality of existing models can be improved and other control strategies can be investigated by simulating deep-bar induction generators and more complex models of drive trains.

5 Conclusion

It is possible to mitigate the climate change and GHG emissions to a certain level, though not completely, by human beings. The Climate Change, Mitigation and Adaptation have been reviewed in view of IPCC and clean development mechanism (CDM), one of the most recommended and promising technology for mitigation, introduced under the Kyoto Protocol is reviewed vis-à-vis PAT and REC Mechanism. Cost-effective and immediate to implement Energy Efficiency and energy saving certification is the need of the hour. Funding for GHG mitigation projects in developing countries is crucial for addressing the global climate change problem. The existing policies and the amendments needed in the framing of new policies have been reviewed. The portfolios of policy instruments used by the industrialized countries in their evolving climate change strategies should be widened, increasing the coverage of those policy instruments to all sectors. In scaling the policy responses to climate change, local thinking must be coupled with global and national scales of action in order to achieve the levels of CO_2 reductions needed to avoid dangerous climate impacts.

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