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# JOURNAL OF ENERGY AND MANAGEMENT

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**ENERGY AND MANAGEMENT**

**VOL. 1. NO. 2**

# CONTENT

**EDITORIAL**

We are happy to present the second issue of Journal of Energy and Management with five research papers on different aspects of energy and management. We are happy to inform both our authors and readers that we have completed the formalities for RNI and ISSN registration and this issue, in fact, carries the ISSN number.

A brief introduction of the five papers that are the highlights of this issue is given ahead.

The first paper in this issue "Impact of Huge Variation in Cost of Debt and Reverse Auction Process on Feasibility of Solar PV Projects under Present Policy Framework in India" analyzes impact of financial challenges posed by variation in cost of debt and reverse auction process on economic feasibility of projects. This analysis has been carried out by comparing cash flows and other financial parameters such as Net Present Value (NPV), Internal Rate of Return (IRR), and Pay Back Period (PBP).

The second paper titled "Model Predictive Control of Series Compensation for Transient Stability Enhancement of Smib System" discusses stability issues with increases in electrical power demand in the context of existing transmission facility. As higher loading will result in reduction in transient stability margin, it is necessary to carry out transient stability analysis and it becomes very important to find techniques by which transient stability can be improved. Thyristor controlled series capacitor is one of the FACTS controller which is well known for transient stability improvement. In this paper one of the popular optimal control strategies named model predictive control (MPC) is presented for Thyristor Controlled Series Capacitor (TCSC) control. Generator rotor angle is taken as reference signal to derive optimal control input. TCSC's effectiveness to enhance transient stability and damping of electromechanical oscillations are examined and presented in the paper. This simulation was carried out in Matlab environment.

The third paper in this issue "Transient Case for Sub-Synchronous Resonance Study" develops models for study of Sub-synchronous resonance (SSR), which has been the topic of discussion and incisive studies the recent times. Models in this paper were developed with minimum sophistication needed to obtain useful results of transient case.

The fourth paper in this issue, "Changing Energy Dynamics in Europe", explores how the newly emerging energy game and changing trends in Europe could possibly influence the energy map of the world. The paper discusses changing government policies, factors affecting energy business in Europe, and hedging strategy of major energy-utility companies, mainly utility and midstream sector organizations. The paper also studies the dynamics from the perspective of the world energy market.

The fifth paper, "Do MSMES Practice Energy Conservation Principle: A Case of Gujarat", attempts to study current policy framework of Government in India, more specifically with reference to Gujarat, and examines energy conservation practices among Medium, Small and Micro Enterprises (MSMEs) in context of the present policy environment. The paper attempts to study measures adopted by selected MSMEs in different districts in the state of Gujarat.

We take this opportunity to thank all our contributors to the inaugural issue as well as the present issue of the journal. Their sustained support has been the driving force for us at the editorial office. We also record our appreciation of and gratitude to our reviewers for their continued timely support, which has always helped us to choose the right quality papers for publication in our journal.

*- C. Gopalkrishnan*

***Journal of Energy and Management (JEM)*** is an International referred peer-reviewed journal. Journal of Energy and Management welcomes original papers from both academicians and practitioners on experimental energy science and technology (conventional and non-conventional), energy sector related management, business, and organizational issues related to energy and research. Papers, based on theoretical or empirical research or experience, should illustrate the practical applicability and/or policy implications of work described.

The bi-annual journal carries many features including perspectives, conceptual research, empirical research, colloquium, management case, and book reviews. Authors are invited to submit their contribution under any feature.

**AIM AND SCOPE**

The proposed research journal shall report and focus on identifying new opportunities, challenges, best practices and strategies for global economy on various complementing issues like business & techno-managerial Issues, regulatory & policy matters, marketing issues, financial & accounting issues, operational excellence & management, social & human resource management and capacity building in general and energy sector in specific.

JEM is a peer reviewed journal and follows a 'double blind' review process. All the papers submitted to JEM go through a preliminary review at the editorial desk and those considered appropriate are sent to an Editor representing a specialized domain. On recommendation of the concerned Editor, the Article may be rejected or assigned to two reviewers.

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# IMPACT OF HUGE VARIATION IN COST OF DEBT AND REVERSE AUCTION PROCESS ON FEASIBILITY OF SOLAR PV PROJECTS UNDER PRESENT POLICY FRAMEWORK IN INDIA

**Nisarg Shah, Urvi Mehta, Indrajit Mukhopadhyay**

**KEYWORDS**

Solar PV, Energy Policy, Project Feasibility, India, Financial challenges, Reverse auction

**ABSTRACT:** The Union Government as well as many State Governments of India has introduced solar PV policies to promote solar PV technologies. The key feature of these policies is selection of through reverse auction. Currently, huge variation in cost of debt is prevailing in Solar PV market. In this paper, impact of financial challenges posed by variation in cost of debt and reverse auction process on economic feasibility is analyzed This analysis has been done by comparing cash flows and other financial parameters such as Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Back Period (PBP).

## 1. INTRODUCTION

India has a very high potential for solar energy as most of its regions have around 300 clear sunny days with solar radiation ranging from 4 KWh/m2 to 7 KWh/m2. The Indian energy portal estimates that 12.5 % of India's total land mass or in other words, the area of around 43,000 Km2 can be used to generate solar energy.

In the year 2008, Govt. of India has launched National Action Plan on Climate Change (NAPCC) in order to address the issues related to climate change. The NAPCC is divided into eight missions that address critical issues related to climate change (Government of India, 2008). NAPCC has outlined measures to advance technological deployment, technological shift and other adoption methods to mitigate effects of climate change. As per this action plan, The Union Government (Central Government) has decided to increase the share of renewable energy up to 15% of total energy generation through favourable energy policies.

To promote renewable energy market, Central Government has set targets for Renewable Purchase Obligation (RPO), in which power utility companies and captive power consumers have to purchase certain quantity of renewable energy. As per the direction given by the Central Government under Electricity Act 2003, various State Electricity Regulatory Commissions (SERCs) have set their respective RPO targets. SERCs have outlined specific RPO targets for different renewable technologies such as bio gas, wind energy and solar technologies. (Solar PV and Solar thermal) (Ministry of Law & Justice, 2003).

As per NAPCC, various State Governments and Central Government have introduced solar energy polices to promote investment in solar PV technologies at large as well as small scale. The market growth of Solar PV is very promising in India but at the same time many articles have been published highlighting financial challenges faced by the project developers. In India, project developers can be classified broadly in two main categories:

- Domestic Project developers: These project developers can finance their projects by acquiring loan either from domestic banks or from foreign banks by hedging foreign currency.

- Multinational project developers: These project developers can finance their projects by acquiring loan from foreign banks without hedging foreign currency.

Project developers have mainly three solar policies under which they can develop large MW scale Solar PV plants.

The solar policy framework is in place since the year 2010 in India. However, there is still ambiguity about attaining financial feasibility of solar PV projects under existing solar energy policies due to huge variation in cost of debt and competition among them in the reverse auction process (reverse competitive bidding).
In reverse auction process, first, the government defines total capacity, to be allotted with provision of maximum level of supporting incentives (such as feed in tariff or capital subsidy). The declared capacity will be allotted through reverse auction process in which the interested project developers have to bid (for project of desired capacity) with lower requirements of supporting incentives than maximum level. The project developers (bidders) with lowest requirement of supporting incentives will be selected and invited to sign agreement for developing solar PV plants. This process is similar to tender process implemented in Ireland in the year 1994. Similar kind of tender processes are currently in place in France as well as in Denmark. (Kitzing, Mitchell, & Morthorst, 2012).

This paper aims to assess the financial feasibility of grid connected MW scale solar PV projects attained by different project developers under present state level solar policies as well as national level solar policy known as Jawaharlal Nehru National Solar Mission (JNNSM). It analyzes ability of existing solar policies to attract different types of project developers. Three states (Sharma, Tiwari, & Sood, 2012) namely Gujarat, Rajasthan & Tamil Nadu with the most favourable solar radiations are selected for this analysis.

The objectives for the above mentioned analysis are as follows:

- It will give an idea about existing solar policies in India.

- It will provide an estimation of financial feasibility attained by different categories of project developers for their large scale solar PV projects under JNNSM and state level solar policies.

- It gives basis to the government stakeholders for new improvement in solar policies in such a way that the impact of financial challenges faced by the project developers can be mitigated.

## 2. OVERVIEW OF SOLAR POLICIES

Existing solar policies in India can be classified in three main categories, under which project developers can develop large scale solar PV plants:

- Renewable Energy Certificate (REC) mechanism,
- National level solar policy (i.e. JNNSM)
- Various state level solar policies

**REC Mechanism:** REC is a market driven mechanism in which project developers, who have not signed PPA under JNNSM or state level solar policies with any kind of benefits (such as feed in tariff, capital subsidy, tax exemption etc.) can avail REC certificate for every sale of 1000 MWh electricity at market price prevailing in the Energy Exchange. This mechanism has been adopted from concept of green certificates prevailing in few European countries such as UK and Italy. (Kitzing et al., 2012) These certificates can be traded through Energy Exchange within price band decided by CERC from time to time. Potential buyers of these certificates are captive consumers and electricity utility companies who can't comply with their RPO targets by developing Solar PV plants themselves. Central Govt. has not outlined REC price band beyond the year 2017. There is too much uncertainty and ambiguity regarding future of this mechanism. Thus, getting financial closure of Solar PV project under this mechanism is mostly impossible in the absence of Government guidelines for future REC prices. Therefore, this mechanism is not considered for subsequent analysis with assumption that that under the existing condition, project under this mechanism is not economically viable. (Central Electricity Regulatory Commission, 2014b).

**Jawaharlal Nehru National Solar Mission (JNNSM):** JNNSM was announced in the year 2010 by the Central Govt. of India in order to promote solar based technologies. This mission has set ambitious target of setting- up 20 GW of solar based power plants by the year 2022. The details of phase wise deployment of solar based generation are shown in Table 1 (Ministry of New & Renewable Energy, 2012).

***TABLE 1*** *Capacity addition targets under JNNSM*

| Segment | Phase I (2010-13) | Phase II (2013-17) | Phase III (2017-22) |
|---|---|---|---|
| **Utility grid Power (incl. rooftop)** | 1100 MW | 10,000MW | 20,000MW |

Under JNNSM Phase 1 (from year 2010 to year 2013), total capacity of 950 MW was allotted in two separate batches for solar PV technology with maximum feed in tariff of Rs. 17.10 for batch 1 and Rs. 15.4 for batch 2. The projects were selected through reverse competitive bidding route in which project developers had to bid with lower tariff than declared feed in tariff. The projects were selected with an average tariff of Rs. 12.12/kWh for 25 years in batch 1 and with an average tariff of Rs.8.77/kW for 25 years in batch 2. (Ministry of New & Renewable Energy, 2013).

In the year 2013, JNNSM Phase 2 was initiated. Under Phase 2, total capacity of 750 MW has been allotted for solar PV technology. Project developers still resist for investing in solar PV projects due to the upfront capital investment, required commercial viability and issues relating to attaining financial closure because of weak balance sheets of nodal agencies as well as utility companies with whom PPA had to be signed. Considering above constraints under Phase 2, capital subsidy in terms of VGF is offered by the government to attract more investment in solar PV projects. Features of VGF are mentioned as follows:

- In order to reduce financial burden on utility companies, tariff of Rs.5.45/kWh is fixed for 25 years.
- Govt. will provide VGF either up to maximum 30 % of capital cost or Rs. 250 million/MW, whichever is lower.
- The projects will be selected through reverse auction process route, in which project developers have to bid for a project of desired capacity with requirement of VGF (equal or less than 30% of the capital cost). The total capacity of 750 MW declared in JNNSM phase 2 will be allotted to bidders with the lowest VGF requirement (Ministry of New & Renewable Energy, 2013). Similar kind of tender process was implemented in Ireland (in AER 1) in year 1994.(Kitzing et al., 2012).

**State Level support schemes:** In addition to JNNSM, many State Governments in India have launched state level solar policies with additional allocation capacity separated from JNNSM to promote solar PV in their states. They have introduced preferential tariff (feed in tariff) higher than the market price of electricity to support market development of solar PV. As mentioned in pervious section, three states namely Gujarat, Rajasthan and Tamil Nadu have been selected for this analysis. The feed in tariff and key features of state level solar policies of selected states are explained in Table 2:

| States | Declared tariff By SERC (for 25 years) | Key features | Nodal agency |
|---|---|---|---|
| Gujarat | 6.77 (Rs/KWh) (Gujarat Electricity Regulatory Comission, 2015) | • Electricity duty on power generated by solar PV projects is exempted.<br>• Gujarat Electricity Transmission Corporation (GETCO) is facilitating installation of transmission line between power plant and nearer substation.<br>• Cross subsidy surcharge is not applicable for open access obtained for third party sale within the state.<br>• Wheeling & transmission charge will be 2 % of total energy fed in to the grid (Govt. of Gujarat, 2009). | Gujarat Energy Development Agency (GEDA): It helps project developers in identifying land, providing necessary water supply at the site and other clearance procedures(Govt. of Gujarat, 2009**).** |
| Rajasthan | 6.74 (Rs/KWh) (Rajasthan Electricity Regulatory Comission, 2015) | • Government land will be allotted. Necessary water supply will also be provided by the State Government.<br>• Industrial grant applicable under state industrial promotion scheme will be provided to solar PV projects<br>• Electricity duty on power generated by solar PV will be exempt(Rajasthan Renewable corporation Ltd, 2014) | Rajasthan Renewable Energy Corporation (RREC): It is nodal agency for providing necessary approval, process of land allotment, bidding process and project registration process. It will also help to coordinate with the State Government and getting loans & grants if required. (Rajasthan Renewable corporation Ltd, 2014) |
| Tamil Nadu | 7.01 (Rs/KWh) (Tamil Nadu Electricity Regulatory Comission, 2014) | • Solar Power plants have been identified at industrial units by state government and tax benefits as per Tamil Nadu industrial policy will be provided.<br>• 100% Electricity duty exemption will be provided for first 5 years from the date of commissioning (Govt. of Tamil Nadu, 2012) | Tamil Nadu Energy Development Agency TEDA:<br><br>It is a nodal agency for single window clearance which includes all statutory clearances, approval of power evacuation from state transmission utility and clearance from pollution control board within 30 days. So the project will be commissioned in first 12 months from signing PPA (Govt. of Tamil Nadu, 2012)**.** |

Until now all the states except Gujarat have introduced reverse competitive bidding in feed in tariff declared by their SERCs. However in 2015, even the State Gujarat has introduced reverse competitive bidding in feed in tariff. The project developers bidding with lowest tariff than declared maximum feed in tariff will be given opportunity to sign PPA. Currently, similar kind of tender process is implemented in France. (Kitzing et al., 2012).

## 3. THEORETICAL BACKGROUND OF FINANCIAL PARAMETERS USED FOR THIS ANALYSIS

In this section, financial parameters used for this feasibility analysis are explained.

Cost of Equity: Cost of Equity is the rate of return which shareholders ask as compensation for investing their capital. In this paper, cost of equity is estimated using bond-yield -plus- risk premium approach. According to this approach, cost of equity is divided in two parts, a) base rate of government bonds, which is also called risk free return and b) risk premium asked by equity holders for investing their equity. It is represented by the following formula (Baker & Powell, 2009):

$$k_e = b_r + R_p \quad (1)$$

Where $(k_e)$ is cost of equity is, $(b_r)$ is base rate of government bond and $(R_p)$ is risk premium.

Risk premium is linearly proportional to risk involved in project in which equity is invested. Risk estimation is very subjective matter, thus, risk premium asked by equity holder is also very subjective. In India, cost of equity asked by shareholders ranges from 10% to 15% (Nelson, Shremali, Goel, Kanda, & Kumar, 2012), lower than expectation of shareholders investing in matured solar markets of Europe and US. The reason behind lowering cost of equity is to increase market share in newly emerging solar market. In India, Project developers charge very low risk premium of 2% (below market level) to maximum 7 % in order to increase market despite of lots of risk involvement in solar PV project.

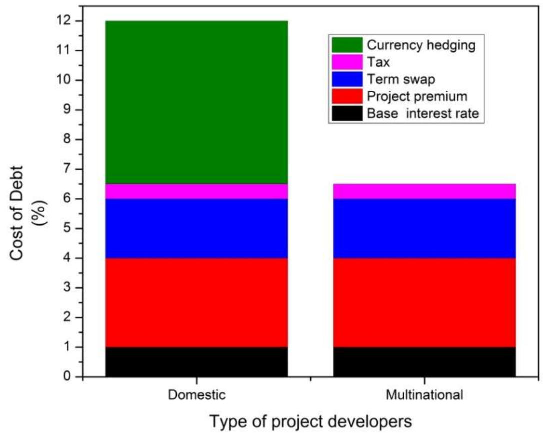
**Cost of Debt:** Cost of debt is the rate of interest expected for lending money. Usually, the rate of interest on debt prevailing in the market is referred as cost of debt before tax. The rate of interest after adjusting tax is referred as effective cost of debt (Khan and Jain, 2007) represented by:

$$k_{de} = k_d(1 - T) \quad (2)$$

Where $(k_{de})$ is effective cost of debt, $(\mathrm{k_d})$ is the cost of debt before tax and $(T)$ is tax rate.

In developing country like India, growth requires with huge investment in infrastructure project. This requirement creates huge demand of debt finance, resulting high interest rate (Nelson et al., 2012). The other sources of debt funding such as corporate bond markets and non-banking financial institutions are underdeveloped. Risk perception due to poor credit rating of many state electricity utility companies (B+ or less) and asset liability mismatch forced many commercial banks to put restriction in financing solar projects (Umamaheswaran & Rajiv, 2015). This self-imposed restriction by local commercial banks resulted in scarcity of debt fund in the local market. Under this condition, domestic project developers are left with only one alternative: to get debt fund from foreign lenders. However, due to high volatility in currency exchange, domestic project developers have to hedge foreign currency which adds about 5 to 7 % to the cost of debt (Nelson et al., 2012). On the other side, due to receivable income in foreign currency, multinational project developers can save cost of currency hedging, which gives them significant edge over domestic project developers. The breakup of cost of debt acquired by domestic developers and multinational developers are shown in Figure 1:

**FIGURE 1:** *Breakup of cost of debt acquired from foreign lenders**




**Domestic project developers have to pay very high cost of debt compare to multinational project developers due to high cost of currency hedging (Nelson et al., 2012)*

Annual Cash flow (after tax): Annual cash flow after taxation is calculated by the following formula:

$$C_t = I_n - T_n \quad (3)$$

$$I_n = E_n * T_{Kwh} - C_{o\&m} - I_c - I_p \quad (3.1)$$

$$T_n = (I_n - Dp) * T \quad (3.2)$$

Where $(C_t)$ is annual cash flow after tax, $(I_n)$ is annual taxable income, $(T_n)$ is annual payable tax $(E_n)$ is annual exported energy to grid, $(T_{Kwh})$ is Tariff for exported energy to grid, $(C_{o\&m})$ is annual O&M cost, $(I_c)$ Annual payable insurance premium, $(I_p)$ interest paid, $(Dp)$ annual allowable depreciation as per taxation law and $(T)$ is annual tax rate.

**Weighted Average Cost of Capital (WACC):** WACC represent minimum rate of return which is used for discounting cash flows generated by the business asset. WACC must be greater than or equal to cost of financing those assets employed in proportions. WACC is calculated based on following formula (Hawawini & Viallet, 2011):

$$WACC = \frac{D}{E+D} k_d (1-T) + \frac{E}{E+D} k_e \quad (4)$$

Where (*D*) represents Cost of debt , (*E*) is equity, $(k_d)$ is cost of debt before tax, $(k_e)$ is cost of equity and (*T*) is tax rate.

**Net Present Value (NPV):** Net Present Value (NPV) is calculated based on following formula:

$$\sum_{t=1}^{N} \frac{C_t}{(1+r)^t} - C_0 \quad (5)$$

Where (N) is project life time (yrs.), $(C_t)$ is annual cash flow at $t^{th}$ year, ( $r$ ) is WACC and $(C_0)$ is initial capital investment.

**Selection criteria for project based on NPV:** If NPV of project is positive, the project is feasible & generating a profit (Keown & Martin, 2009). However, if NPV is negative, project is not feasible & is creating a loss (total cost of financing business assets employed in the project is higher than profit generated by the project).

Among the projects with positive NPV, the project with higher NPV is considered more feasible.

**Internal rate of return (IRR):** IRR is calculated based on the following formula:

$$C_0 - \sum_{t=1}^{N} \frac{C_t}{(1+IRR)^t} = 0 \quad (6)$$

Where the terms have their usual meaning presented in previous equations.

Projects with IRR greater than WACC is considered as financially feasible. *(Keown & Martin, 2009)*.

In this paper, IRR of equity cash flows is calculated. Therefore, the project becomes financially feasible only if IRR of equity cash flow is higher than the cost of equity.

## 4. RESEARCH METHOD

This paper aims to analyze financial feasibility of grid connected MW scale solar PV project attained by different project developers under present state level solar policies as well as JNNSM.

As mentioned in the previous section, broadly, project developers in India can be classified in two categories. Further they are classified in four sub categories for the following analysis.

**Type A:** These are the domestic companies which can borrow loan either from domestic banks or from foreign banks by hedging foreign currency. These companies keeps their cost of equity very low (around bond yield rate) with lowest risk premium.

**Type B:** These are the domestic companies which can borrow loan either from domestic banks or from foreign banks by hedging foreign currency. Cost of equity of these companies is high because of market driven risk premium.

**Type C:** These are the multinational companies which can borrow loan from foreign banks without hedging foreign currency. These companies also keeps their cost of equity very low (around bond yield rate prevailing in that country) with lowest risk premium.

**Type D:** These are the multinational companies which can borrow loan from foreign banks without hedging foreign currency. . Cost of equity of these companies is high because of market driven risk premium.

The assumption of cost of debt and cost of equity of all these four types of project developers are shown in Table 3.

***TABLE 3:*** *Cost of debt and Cost of equity of four types of project developers selected for this analysis*

| Type of Project Developers | Cost of debt (%) | Cost of equity (%) |
|---|---|---|
| **Type A** | 12.00 | 10.00 |
| **Type B** | 12.00 | 15.00 |
| **Type C** | 6.00 | 10.00 |
| **Type D** | 6.00 | 15.00 |

As mentioned in previous section, three states with the highest solar irradiation namely Gujarat, Rajasthan and Tamil Nadu have been selected for this analysis. Selections of locations at different states are done based on their favourable solar irradiation level and ease of land allocations facilitated by various state governments for Solar PV plant development. The latitude and solar irradiation data of selected locations are mentioned in following Table 4.

***TABLE 4.*** *Latitude and annual solar irradiation data of selected locations*

| Locations | Latitude & Longitude | GHI (kWh / sq. m) (annually) |
|---|---|---|
| **Charanka - Gujarat** | 23.9°N & 71.2°E | 2063.1 |
| **Jodhpur - Rajasthan** | 26.3°N & 73.0°E | 2306 |
| **Ramanathapuram - Tamilnadu** | 9.4°N & 78.9°E | 1887 |

This study aims to answer mainly four questions:

- How much financial feasibility of solar PV projects under JNNSM is attained by different types of project developers without any reverse competitive bidding in VGF at selected locations?
- How much financial feasibility of solar PV projects under state level solar policies attained by different types of project developers without any reverse competitive bidding in feed in tariff (FiT) at selected locations?
- How reverse competitive bidding in VGF will impact financial feasibility of solar PV projects under JNNSM attained by different types of project developers at selected locations?
- How reverse competitive bidding in FiT will impact financial feasibility of solar PV projects under state level solar policies attained by different types of project developers at selected locations?

The technical design and simulation of PV plant at different locations is carried out using PV Syst software (PVSYST, 2013). In absence of any scientific publications in this area, input parameters for simulations are assumed on basis of practices, followed by EPC (Engineering, Procurement and Construction) service providers in India. Financial input parameters are assumed based on various regulatory orders and government documents.

For simulation, polycrystalline silicon based modules have been selected. Other technical specifications of solar PV plant assumed for simulation are mentioned in following Table 5

***TABLE 5.*** *Technical specifications of Solar PV plant*

| Technical specification | Data |
|---|---:|
| **Plant Capacity** | 5 MW |
| **Module capacity** | 275 Wp |
| **module life time** | 25 Years |
| **Inverter capacity/total no. of inverter** | 500KWac/ 10 |
| **Inverter life time** | 13 Years |

- The degradation rate of solar PV plant performance is assumed at 1% per year.
- Tilt angle of PV module w.r.t horizontal plane is assumed as latitude of location and azimuth angle is assumed as zero (south facing).

Other input data assumed for this feasibility study are mentioned in the following Table 6.

***TABLE 6.*** *Financial inputs used for this feasibility study*

| Financial Parameters | Values |
|---|---|
| **Capital Cost** | Rs. 60500000 (Rs. /MW) |
| **O & M cost** | Rs. 1512500 (for 5MW)(with escalation of 5.72% per year) |
| **Insurance Cost** | Rs. 1512500 (Fixed) (for 5 MW) |
| **Debt: Equity Ratio** | 70% : 30% |
| **Loan tenure** | 10 years |
| **Minimum Alternative Tax rate (first 10 years)** | 20.08% |
| **Corporate tax** | 32.45 % |

Like any other democratic country, changing corporate tax drastically is very politically sensitive issue and also has major impact on overall economy. So, it is assumed that corporate tax will remain stable throughout the project life cycle.

The cost of land is included in capital cost. Capital cost specified in Table 5 is decided from the regulatory order of benchmarking capital cost of Solar PV project by CERC (Central Electricity Regulatory Commission, 2015)

To promote Solar PV, Govt. of India has declared tax holiday for the first 10 years in interim Budget 2014-15 in July, 2015. However, as per Income tax section 115JB, if tax payable is less than 18.5% of book profit, then concerned companies have to pay Minimum alternative tax (MAT) at a rate declared in CERC tariff order(Central Electricity Regulatory Commission, 2014a).

Administrative and other costs such as wheeling charges and transmission costs are included in O & M cost.

It is assumed that O & M cost will escalate at the rate of 5.72% per year (as per CERC Order) (Central Electricity Regulatory Commission, 2014a)

Inverter life time is assumed as 13 year (Gujarat Electricity Regulatory Commission, 2015) and its replacement cost is added in O&M cost of 13th year

Project developers always discount their cash flows with high cost of equity because high cost of equity is always associated with high risk factor. To negate effect of risk, in this paper, risk free component of cost of equity is considered as 8% (interest rate given on various long term government bonds issued by the Govt. of India) per annum.

The benefit of accelerated depreciation is not considered in this analysis

Using output of technical simulation & financial input parameters mentioned above, annual cash flows of solar PV project are calculated at all selected locations using eq.3. For each selected location, four different cash flows of single project under same policy are generated (by varying WACCs of all four different types of project developers). So, for each selected location, there are total eight cash flows (four of same project under state level policy & four of same project under JNNSM)

As a first step of feasibility analysis, NPVs of all eight cash flows of the solar PV project at each selected location are calculated.

At second step, impact of reverse competitive bidding (in VGF in case of JNNSM & in feed in tariff in case of state level policies) is measured by performing sensitivity analysis (Bidding VS WACCs of different project developers) and analyzing sensitivity of NPV.

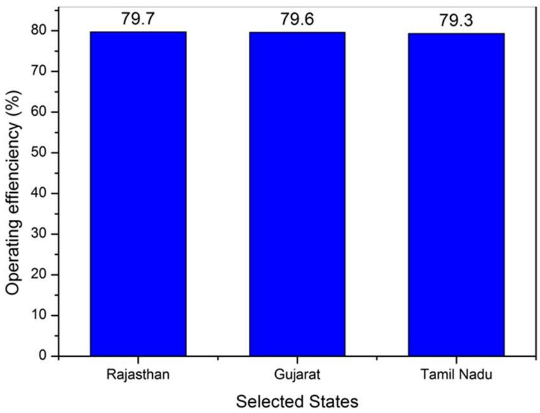
At third step, IRR -equity and PBP of all Cash flows with positive NPV are calculated.

## 5. RESULTS AND DISCUSSION

The results of PV system simulation are shown in Figure 2 & Figure 3. From the results, it can be observed that the highest energy generation is in Rajasthan followed by Gujarat and Tamil

Nadu. Performance Ratio of Solar PV plants in all selected locations are turning out to be approx. 80%, while transmission loss from plant to grid is turning out to be 2% to 5% .

***FIGURE 2:*** *Power generation by solar PV plant in first year after commissioning of project*




The results of feasibility analysis of solar PV plant under state level policies and JNNSM for each selected location are shown in Table 7 & Table 8 respectively and discussed subsequently.

**Rajasthan:** Rajasthan has the highest solar radiation (see Table 4) among selected states. Due to very high solar radiation, potential of energy generation from Solar PV project in this state is the highest among the selected states (see Figure 2). The highest solar potential will attract many project developers for bidding. In case of projects under JNNSM, it can be observed (from Table 8**)** all four types of project developers can make project feasible with positive NPV and high IRR- Equity in absence of reverse bidding process in VGF (capital subsidy). However, as aggression in bidding increases due to competition, the scope of making project feasible decreases and only the project developers of Type C can make project feasible without any requirement of capital subsidy. In case of project under state policy, it can be observed from Table 7 that the project developers of Type B can't make project feasible even if there no reverse competitive bidding process and full capital subsidy is given to them. While, The other project developers (Type A, Type B and Type C) can make project feasible with reasonable profit and survive in certain level of bidding. However, as competition in bidding increases, their ability to make feasible project decreases.

**Gujarat:** Gujarat has also favourable condition for solar PV project in terms of solar radiation (see Table 4). It is the second best location for solar PV project among the selected states with potential of energy generation lower than Rajasthan but higher than Tamil Nadu (see Figure 2). From Table 8, it can be observed that in case of Solar PV project under JNNSM, project developers of Type B can't make project feasible even if full capital subsidy is given to them (in absence of any reverse competitive bidding) while Other three types of project developers can make project feasible with full capital subsidy. Under reverse competitive bidding process, only project developers of Type C have best scope of making project feasible. However, they also cannot survive in absence of capital subsidy. From Table 7, it can be observed that in case of the Solar PV project under state level policy, only the project developers of Type C can make project feasible irrespective of level of aggression in bidding.

***TABLE 7.*** *Results of feasibility analysis of projects under state level policies: (with and without competitive reverse bidding)**

| State | Bidding with reduction in tariff | Type | NPV (Rs. Millions) | IRR -Equity (%) | PBP (Yrs.) |
|---|---|---|---|---|---|
| Gujarat | 0% (without any competitive bidding) | A | -20.35 | N/A | N/A |
| | | B | -78.02 | N/A | N/A |
| | | C | 57.84 | 20 | 8 |
| | | D | -5.46 | N/A | N/A |
| | 5% | A | -38.31 | N/A | N/A |
| | | B | -92.82 | N/A | N/A |
| | | C | 37.75 | 18 | 8 |
| | | D | -22.19 | N/A | N/A |
| | 10% | A | -56.27 | N/A | N/A |
| | | B | -107.63 | N/A | N/A |
| | | C | 17.66 | 16 | 9 |
| | | D | -38.92 | N/A | N/A |
| Rajasthan | 0% (without any competitive bidding) | A | 20.73 | 19 | 8 |
| | | B | -44.17 | N/A | N/A |
| | | C | 103.77 | 24 | 7 |
| | | D | 32.79 | 24 | 7 |
| | 5% | A | 0.69 | 17 | 8 |
| | | B | -60.66 | N/A | N/A |
| | | C | 81.39 | 22 | 7 |
| | | D | 14.15 | 22 | 7 |
| | 10% | A | -19.31 | N/A | N/A |
| | | B | -77.31 | N/A | N/A |
| | | C | 59.00 | 20 | 8 |
| | | D | -4.49 | N/A | N/A |
| Tamil Nadu | 0% (without any competitive bidding) | A | -60.09 | N/A | N/A |
| | | B | -110.78 | N/A | N/A |
| | | C | 13.38 | 16 | 9 |
| | | D | -42.48 | N/A | N/A |
| | 5% | A | -76.06 | N/A | N/A |
| | | B | -123.95 | N/A | N/A |
| | | C | -4.47 | N/A | N/A |
| | | D | -57.36 | N/A | N/A |
| | | | | | |
| | 10% | A | -92.03 | N/A | N/A |
| | | B | -137.11 | N/A | N/A |
| | | C | -22.34 | N/A | N/A |
| | | D | -72.24 | N/A | N/A |

*Highlighted row shows cases of projects feasible with positive NPV

***TABLE 8.*** *Results of feasibility analysis of projects under JNSSM: (with and without competitive reverse bidding).**

| State | Bidding with reduction in VGF requirement | Type of project developers | NPV (Rs. Millions) | IRR-Equity (%) | PBP |
|---|---|---|---|---|---|
| Gujarat | 30%(without any competitive bidding) | A | 23.46 | 20.07 | 8 |
| | | B | -23.51 | N/A | N/A |
| | | C | 82.68 | 25.83 | 6 |
| | | D | 31.31 | 25.83 | 6 |
| | 15% | A | -33.46 | N/A | N/A |
| | | B | -79.64 | N/A | N/A |
| | | C | 31.1 | 18 | 8 |
| | | D | -19.69 | N/A | N/A |
| | 0% | A | -90.38 | N/A | N/A |
| | | B | -135.75 | N/A | N/A |
| | | C | -20.95 | N/A | N/A |
| | | D | -70.7 | N/A | N/A |
| Rajasthan | 30% (without any competitive bidding) | A | 57.95 | 25 | 7 |
| | | B | 4.91 | 25 | 6 |
| | | C | 121.27 | 32 | 7 |
| | | D | 63.44 | 32 | 6 |
| | 15% | A | 1.03 | 17 | 8 |
| | | B | -51.2 | N/A | N/A |
| | | C | 69.67 | 22 | 7 |
| | | D | 12.44 | 22 | 7 |
| | 0% | A | -55.89 | N/A | N/A |
| | | B | -107.32 | N/A | N/A |
| | | C | 18.08 | 16 | 9 |
| | | D | -38.56 | N/A | N/A |
| Tamil Nadu | 30% (without any competitive bidding) | A | 7.72 | 15 | 9 |
| | | B | -57.15 | N/A | N/A |
| | | C | 37.04 | 19 | 9 |
| | | D | -6.68 | N/A | N/A |
| | 15% | A | -74.25 | N/A | N/A |
| | | B | -113.27 | N/A | N/A |
| | | C | -14.54 | N/A | N/A |
| | | D | -57.69 | N/A | N/A |
| | 0% | A | -131.17 | N/A | N/A |
| | | B | -169.39 | N/A | N/A |
| | | C | -66.13 | N/A | N/A |
| | | D | -108.7 | N/A | N/A |

*Highlighted row shows cases of projects, feasible with positive NPV

**Tamil Nadu:** Tamil Nadu has the lowest solar radiation level and energy generation potential among the selected states (from Table 4 & Figure 2). From Table 8, it can been seen that in case of project under JNNSM, only Project developers with low cost of equity (Type A and Type C) can make project feasible if full capital subsidy is given to them (in absence of reverse competitive bidding). However, none can survive in reverse competitive bidding. From Table 7, it can be observed that only project developers of Type C can make project feasible under state policy if there is no reverse competitive bidding in feed in tariff.

## 6. CONCLUSION AND POLICY IMPROVEMENT

**Conclusion:**

Under present policy framework, domestic Project developers (Type A and Type B) have very little scope of making project feasible only if there is no reverse competitive bidding.

Under reverse competitive bidding (either in JNNSM or in state policies), the multinational project developers with low cost of equity (Type C) have best chance to survive. However, aggression in bidding can reduce their ability to make project feasible significantly.

Three states with the highest solar potential are selected for this analysis. So, based on this analysis, it is safe to assume that project developers have lower scope of making project feasible at other states in India than these three selected states.

**Policy improvement:**

As a variation of solar potential at different locations have very significant impact on project feasibility, in case of JNNSM, The Central government should adopt differential tariff based on locations. So, project developers at all locations have fair chances to make project feasible with acceptable NPV and IRR-equity. While all the State governments should design their policies in such way that their states can also attract project developers by providing alternatives to the states with higher solar potential, such as Rajasthan.

Domination of multinational players may poses serious challenges to energy security of the country So, while designing solar policies, both the Central Government stakeholders and the State Government stake holders should consider high cost of debt bared by domestic project developers (due to either high interest rate asked by domestic banks or high current hedging cost) and revise the policies in such a way that they can get fair opportunity against the multinational players.

To survive in reverse competitive bidding, the project developers have to keep cost of equity at very low level (sometimes even below the market level), which poses serious challenges for them to run their projects with acceptable level of profit. So, until solar markets gets matured, instead of reverse competitive bidding, governments should allot projects on basis of either first cum first serve or by lottery system .

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# MODEL PREDICTIVE CONTROL OF SERIES COMPENSATION FOR TRANSIENT STABILITY ENHANCEMENT OF SMIB SYSTEM

**Miyani Piyushkumar, Vivek Pandya, Anilkumar Markana**

**KEYWORDS**

TCSC, Model Predictive control, SMIB

**ABSTRACT:** Increase in electrical power demand in the fast manner in comparison of building of transmission facility, loading on existing transmission facility increase day by day. This will result in reduction in transient stability margin. So now it is necessary to carry out transient stability analysis and it becomes very important to find the techniques by which transient stability can be improved. Thyristor controlled series capacitor is one of the FACTS controller which is well known for transient stability improvement. In this paper one of the popular optimal control strategies named model predictive control (MPC) is presented for Thyristor Controlled Series Capacitor (TCSC) control purpose. Generator rotor angle is taken as reference signal to derive optimal control input. Here, TCSC's effectiveness to enhance transient stability and damping of electromechanical oscillations is presented. This simulation is carried out in mat lab environment.

## 1. INTRODUCTION

Day by day there is increase in the demand of electricity with increase in lifestandards of the peoples and industrial growth. At the same time, establishment of new transmission facility is limited because of various reasons such as cost and large right of way requirement around transmission tower. In this situation, it becomes necessary to increase loading on existing transmission line. Transient stability is one of the limiting factor in loading of long transmission line. If we increase loading it will ultimately results in reduction in the transient stability margin. In this situation there is more chances of machine lose their synchronism. If Flecible AC Ttansmissions(FACTS) controller is installed on the transmission line, it will improve steady state as well as dynamic behavior of power system. Thyristor controlled series capacitor is one of them. TCSC will helps to enhance power transfer capacity of transmission line by providing capactive reactance and also halps to damp out electromechanical oscillations in post fault conditions (Hingorani, Narain G., and Laszlo Gyugyi, 2000).

The control strategy for TCSC is developed to damp out electromechanical oscillation and for the enhancement of transient stability is developed for SMIB and Multi-machine system which is based on energy function is presented by the K.R.Padiyar (Padiyar, K. R., and K. Uma Rao, 1997). The parameter of the controller is tuned from global optimization Multi-start GO is proposed for the two different control strategy namely Lead-Lag compensator and PID controller is presented and implemented for SMIB case where author shows the effectiveness of the controller for the SMIB and he also shows that settling time is less in the all the state of generator (Vikal, Rashmi, and Garima Goyal, 2009).

A genetic algorithm is proposed for the parameter determination of the control structure namely Lead-Lag compensator and PID controller is proposed which is based on integral square error and integral time square error (Panda, Sidhartha, and N. P. Padhy, 2007). The mathematical model of TCSC for transient stability enhancement has been presented by John J. Paserba (Paserba, John J, 1995). Transient stability analysis with fixed series compensation and with PID based TCSC device, comparative analysis is presented (Desai. V, Markana. A, and Pandya. V, 2015).

As the power system is a highly nonlinear system there is need to develop an optimal control strategy for the flexible ac transmission devices as operating point of the power system varies with different loading condition. The model predictive control strategy is one of the most popular control strategies in the process industry and this control strategy can be also used in the power system for the control purpose of FACTs devices like TCSC, static var compensator (SVC) for the single machine with infinite bus and multi-machine system as well for improvement of dynamic performance. In this paper effectiveness of model predictive control schemes using TCSC for single machine with an infinite bus (SMIB) is presented. State space model of power system is required in this optimal control strategy. Here, in this study seven states corresponding to each generator is taken out of which four corresponding to generator internal states and three corresponding to excitation system. It is assumed that all the state measurements are available.

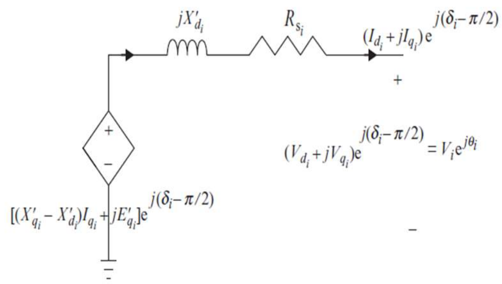
## 2. THE MODELLING POWER SYSTEM AND TCSC

**Modelling of generator:** Transient model of the generator with the following assumptions is taken in this study:

- The stator and network transient are neglected.
- The mechanical power input to the generator is assumed to be constant over the period of transient stability study.
- To observe effectiveness of TCSC of damping electromechanical oscillations in post fault condition damping due to generator is neglected.

With those above assumption the generator can be represented as voltage behind its transient reactance of the machine as shown in Fig (1).

***Figure 1:*** *Dynamic equivalent representation of two axis model of synchronous generator.*




The mathematical modelling of the synchronous generator can be given with the following set of first order differential equations corresponding to its states in transient model such as $\delta i$, $w_i$, $E_{qi}$, $E_{di}$:

$$\frac{d\delta i}{dt} = (w_i - 1)w_b \quad (1)$$

$$\frac{dw_i}{dt} = \left(\frac{1}{2H_i}\right)(P_{mi} - P_{ei}) \quad (2)$$

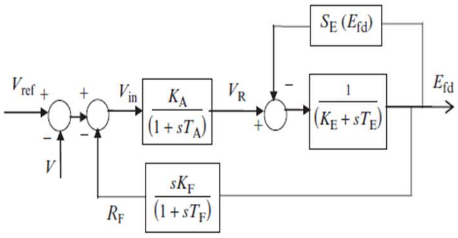
$$\frac{dE_{qi}}{dt} = -\frac{E_{qi}}{T'_{doi}} - \frac{(X_{di}-X'_{di})I_{di}}{T'_{doi}} + \frac{E_{fdi}}{T'_{doi}i} \quad (3)$$

$$\frac{dE_{di}}{dt} = -\frac{E_{di}}{T'_{qoi}} + \frac{(X_{qi}-X'_{qi})I_{qi}}{T'_{qoi}} \quad (4)$$

Where, i=1, 2, 3….number of generator

**Excitation system of the synchronous generator:** IEEE Type 1 excitation system is used in this study. Excitation system can be represented as shown in Fig 2. It consists of voltage regulator and feedback is also there to improve dynamic behaviour of synchronous generator.

***Figure 2:** IEEE Type 1 Exciter model*




The automatic voltage regulator can be given with three first order differential equation which are corresponding to the field voltage $E_{fdi}$,, voltage regulator output $V_{Ri}$ and feedback $R_{Fi}$ .

$$\frac{dE_{fdi}}{dt} = -\frac{K_{Ei}+S_{Ei}(E_{fdi})}{T_{Ei}}E_{fdi} + \frac{V_{Ri}}{T_{Ei}} \quad (5)$$

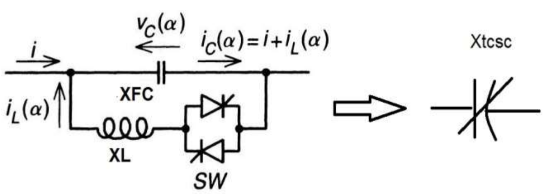
$$\frac{dV_{Ri}}{dt} = -\frac{V_{Ri}}{T_{Ai}} + \frac{K_{Ai}}{T_{Ai}}R_{Fi} - \frac{K_{Ai}\,K_{Fi}}{T_{Ai}\,T_{Fi}}E_{fdi} + \frac{K_{Ai}}{T_{Ai}}(V_{refi} - V_{ti}) \quad (6)$$

$$\frac{dR_{Fi}}{dt} = -\frac{R_{Fi}}{T_{Fi}} + \frac{K_{Fi}}{T_{Fi}^{2}}E_{fdi} \quad (7)$$

Where, i=1,2,3…..number of generator
SEi = 0.0039 (exp (1.555Efdi)

**Thyristor controlled series capacitor model:** The thyristor controlled series capacitor is a structure in which capacitor is connected with two antiparallel thyristors in the series with the inductor. The inductance of the TCSC is varies with different value of firing angle of the thyristor. TCSC diagram is as shown in figure (3).

***Figure 3:** Thyristor controlled series capacitor as variable capacitor*




The mathematical model of the TCSC can be represented with the following set of equations. Apparent reactance of TCSC is overall capacitance of the fixed capacitor and inductive reactance which varies with the firing angle α given to the antiparallel thyristor pair.

$$X\,tcsc\,(\alpha) = \beta 1(X_{FC} + \beta 2) - \beta 4\beta 5 - X_{FC} \quad (8)$$

Where,

$$\beta 1 = 2(\pi - \alpha) + \sin(2(\pi - \alpha))/\pi$$

$$\beta 2 = (X_{FC}\,X_L)/(X_{FC} - X_L)$$

$$\beta 3 = \sqrt{(X_{FC}/X_L)}$$

$$\beta 4 = \beta 3\tan[\beta 3\,(\pi - \alpha)] - \tan(\pi - \alpha)$$

$$\beta 5 = 4(\beta 2^2)\,\cos(pi - \alpha)^2/(\pi X_L)$$

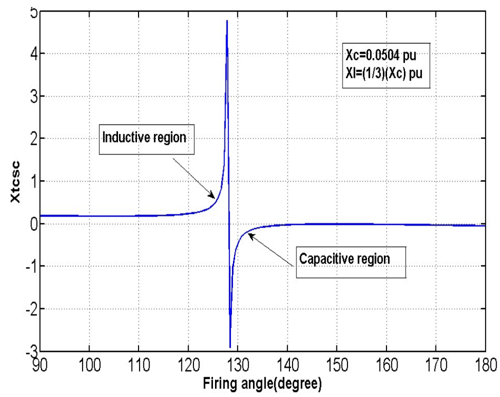
TCSC apparent reactance is changed with the firing angle from 90̊ to 180̊ TCSC reactance is derived and shown in figure (4). From the Figure (4) we can observe that TCSC characteristic divided into two region namely inductive and capacitive regions.

For the firing angle 90̊ <($\alpha$)<($\alpha_{min}$) TCSC operate in inductive region

For the firing angle $(\alpha_{max}) < (\alpha) < 180^{\circ}$ TCSC operate in capacitive region.

In our case study TCSC operation is limited only in capacitive region only.

***Figure 4:** TCSC reactance for different value of firing angle*



## 3. MODEL PREDICTIVE CONTROL SCHEME

The model predictive control scheme is one of the optimal control schemes which uses the system state space model for the giving controlling action and which also guarantees the constraint to be imposed on the outputs, the states and the inputs satisfy very efficiently. The power system can be represented as a set of differential and algebraic equations as follows:

$$\dot{x} = f(x, u) \quad (9)$$

$$y = g(x, u) \quad (10)$$

MPC controller, considered in this work are based on a state-space model of power system in the form of the linearized discrete-time model with sampling time ΔT s = δ = 0.01

$$x(t + \delta) = A\,x(t) + B\,u(t) \quad (11)$$

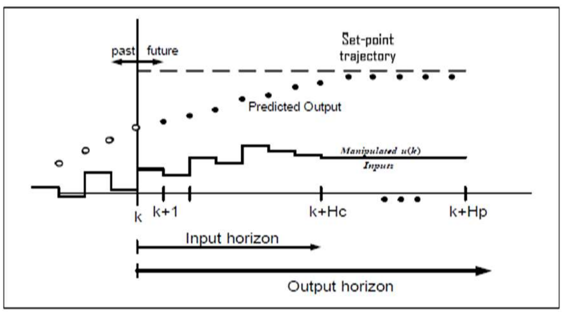
$$y(t) = C\,x(t) \quad (12)$$

Where x∈ $R^n$ is state vector in power system modeling and u is supplementary input from the MPC controller and y ∈Rm is performance measurement vector.

Model predictive control will see the open loop performance of the system over the prediction horizon and this performance vector is compared with the reference trajectory over the prediction horizon and decides optimal control input over the control horizon such that performance vector will achieve its reference point over the prediction horizon.

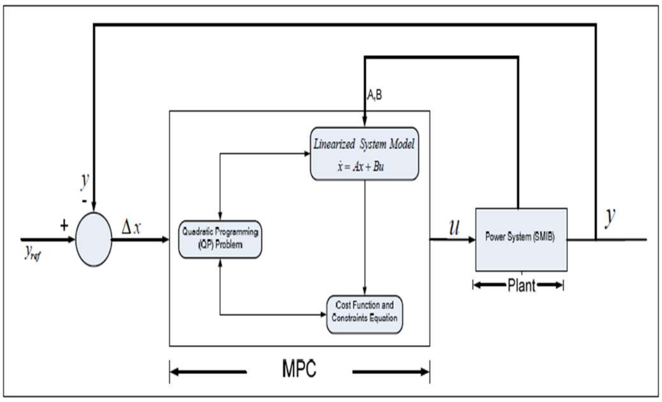
MPC will become receding horizon problem as shown in figure (5).

***Figure 5**: Model predictive control scheme*




The complete power system with MPC is as shown in figure (6).

***FIGURE 6**: Complete power system with MPC controller*




Here, for MPC the discrete time state space model used is linearized model about its steady state operating points.

From that model, the state vector over the prediction horizon can find out iteratively from where the matrix Sx, Su can be found out which are used to solve the objective function which takes the form of quadratic programming.

The quadratic function which was used can be given by the following equation:

$$J = \sum_{j=\delta}^{j=T_P} e_f(t + j/t)\,(W_e)\,e_f(t + j/t) + \sum_{j=\delta}^{j=T\,c-\delta} \Delta u\,(t + j/t)\,(W_u)\Delta u(t + j/t)) \quad (13)$$

Where,

$$e_f(t + j/t) = y_{rf}(t + j/t) - y(t + j/t) \quad (14)$$

Here, $y_{rf}(t + j/t)$ is reference trajectory of future output and $y(t + j/t)$ is estimated future output, we and Wu are weighting matrices on the output error and input value in minimization of the cost function. If we assume p as prediction horizon and q as control horizon then $S_x$, $S_u$ and another matrix useful for optimization can be achieved as follows:

$$Sx=\begin{bmatrix} CA \\ \vdots \\ CA^{q-1} \\ \vdots \\ CA^{p} \end{bmatrix},\ \wedge=\begin{bmatrix} I & [0] & [0] & [0] \\ -I & I & [0] & [0] \\ \vdots & \vdots & \vdots & \vdots \\ [0] & [0] & -I & I \end{bmatrix},\ \wedge_0=\begin{bmatrix} I \\ [0] \\ [0] \\ [0] \end{bmatrix}$$

Su=

$$\begin{bmatrix} CB & [0] & \dots & [0] \\ CAB & CB & \dots & [0] \\ CA^{q-1}B & CA^{q-2}B & \dots & CB \\ . & . & . & . \\ CA^{P-2}B & CA^{P-3}B & \dots & C(A^{p-q-1}+A^{P-q-2}+..+I)B \\ CA^{P-1}B & CA^{P-2}B & CA^{P-3}B & C(A^{p-q}+A^{P-q-1}+..+I)B \end{bmatrix}$$

We can rearrange this term and can quadratic equation in the form of :

$$\min_{Uf}\left(\frac{1}{2}\ U^{T}H\ U\ +U^{T}F(t)\right)$$

Where,

$$H\ =\ 2\ (S_u^T\ W_e\ S_u\ +\wedge^T\ W_u\ \wedge) \qquad (15)$$

$$F(t)\ =\ -2[\ (R(t)-S_x\ x(t/t\ -1)-S_\eta \eta(t))^T W_e\ S_u$$

$$+\ (\wedge_0\ u(t\ -1))^T W_u\ \wedge)] \qquad (16)$$

After solving quadratic problem Δu vector over the control the horizon is obtained out. u vector over the control horizon can be obtained by adding old u vector with Δu vector out of which only first element of the input vector is implemented and at the next sampling period from the available measurement of output then the whole procedure of input vector computation is repeated.

## 4. STIMULATION RESULTS

Synchronous generator is connected to infinite bus via transformer and two parallel line as shown in Fig (1). Data of the single machine connected to infinite bus is mentioned in appendix.

System condition is divided into mainly three parts in any transient stability analysis:

- Prefault (<0.3sec).
- During fault (0.3 sec to 0.36 sec).
- Postfault (>0.3 sec).

In prefault condition network is operated in steady state. Three phase faults is created on line near bus 3 after 0.3sec for analysis purpose which is transient in nature and get automatically cleared after 0.06 sec and system entered into post fault condition. Transient stability analysis is carried out with two different ways to demonstrate effectiveness of TCSC:

- 40% fixed series compensation on both the line between bus 3 and bus 2.
- TCSC is mounted on both the line between bus 3 and bus 2 with MPC control which was initially providing 40% of series compensation to both the line.

Fig(2) to Fig(4) shows simulation results in which angular speed deviation, Excitation field voltage( Efd) and firing angle in case of TCSC availability is shown.

***Figure 7:*** *Single machine connected to infinite bus system.*

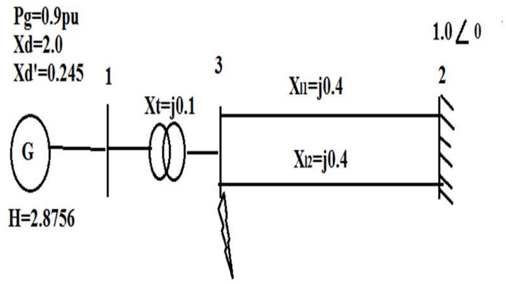



***FIGURE 8:*** *Angular speed deviation for three phase fault*

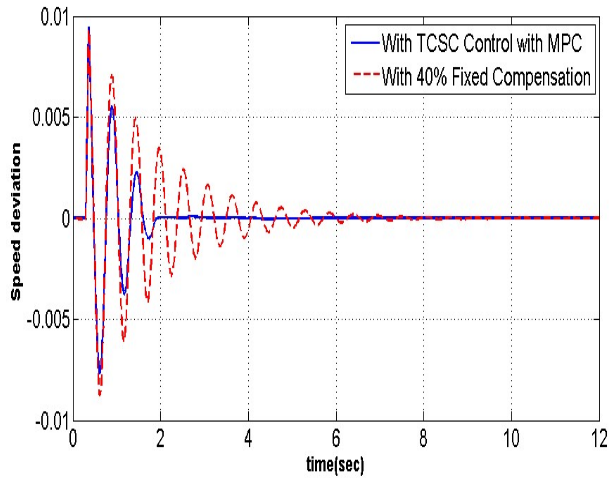


*FIGURE 9: Excitation voltage Efd1*

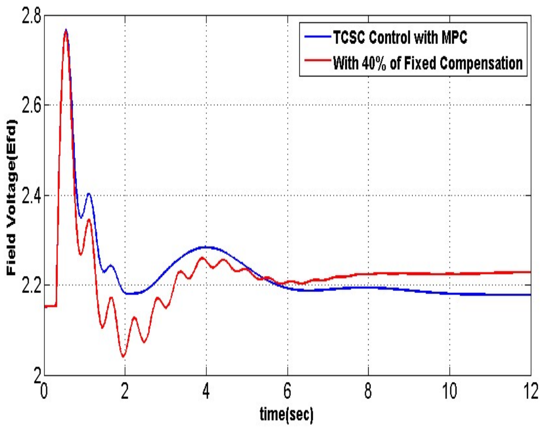
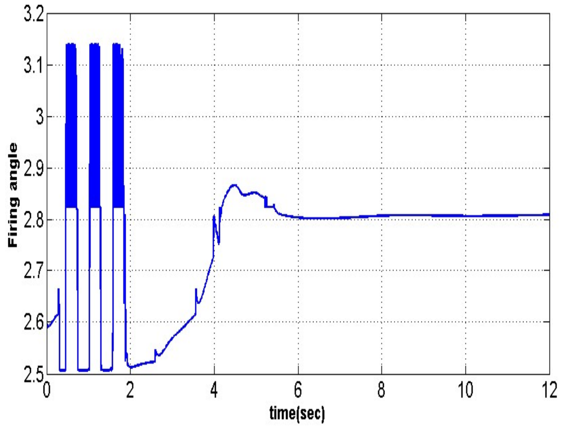



***FIGURE 10:*** *Firing angle of TCSC (rad)*




## 5. CONCLUSION

***TABLE 1:*** *Comparison of power system performance with fixed series compensation and with TCSC*

| Controller type | Generator State | Maximum Peak | ITAE | ITSE |
|---|---|---|---|---|
| **With Fixed series compensation** | Gen. Speed | 0.0094 | 0.9894 | 3.9173e-05 |
| **With Model predictive control for TCSC** | Gen. Speed | 0.0094 | 0.4601 | 2.0812e-05 |

This paper presents transient stability analysis with fixed series compensation and with TCSC availability in place of fixed series compensation. From the simulation results and comparison table which compares result in terms of error criteria such as integral time absolute error(ITAE) and integral time square error(ITSE), it can concluded that TCSC is effectively damped out electromechanical oscillations and help to stabilize the power system.

## APPENDIX

SMIB system data(pu): H=2.8756, D=0.00, Xd1=2.0, Xd'=0.245, Xq=1.91, Xq'=0.245, Xls=0.2, Rs=0.00, Tdo=5, Tqo=0.66, Pe=0.9, f=60 Hz

TCSC data: Xc= 30% of Xl = 0.12 pu, XL = Xc/3 pu, α0=148 degree

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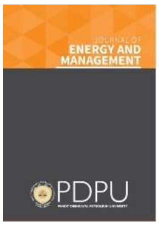


# TRANSIENT CASE FOR SUB-SYNCHRONOUS RESONANCE STUDY

**Sagar Savalia, Vivek Pandya**

**KEYWORDS**
Sub-synchronous resonance, series compensation, Synchronous machine.

**ABSTRACT:** In recent years, much has been written and bibliographies have been published on the subject of Sub-synchronous Resonance (SSR). The model for the study of Sub-synchronous resonance is presented in this paper. Models were developed with the minimum sophistication needed to obtain useful results of transient case.

## 1. INTRODUCTION

In this paper, Series capacitor compensation in AC transmission systems is an economical means to increase load carrying capability, control load sharing among parallel lines and enhance transient stability. However, capacitors in series with transmission lines may cause sub-synchronous resonance that can lead to turbine-generator shaft failure and electrical instability at oscillation frequencies lower than the normal system frequency. Therefore, the effects of SSR must be fully understood and analyzed when planning series capacitor compensation in power systems. The main concern with SSR is the possibility of shaft damage from torsional stresses. Damage can result from the long term cumulative effects of low amplitude torsional oscillations or the short term effects of high amplitude torques. Typically, hydro units have mechanical parameters that are less prone to SSR problems than thermal units.

Sub-synchronous oscillations were first discussed in 1937 [1,2] and until 1971, shaft torsional oscillations were neglected. Two shaft failures at the Mohave Generating Station in Southern Nevada [3] led to the understanding and development of the theory of interaction between series capacitor compensated lines and the torsional modes of steam turbine-generators.

Presently, several computer programs and analytical tools are available for the study of SSR caused by the interaction of multi mass turbine - generators and series compensated transmission systems.

## 2. DATA FOR STUDY SSR

TABLE I shows the impedances for the rotor circuit expressed in per unit on the machine MVA base. Current, voltage, torque and rotor speed are also expressed in per unit. For transient representation, divide reactance in ohms by 377 to obtain the inductance in henries.

The generator standard impedances and time constants from which the circuit parameters of TABLE I were derived are shown in TABLE II. The term XL is armature leakage reactance. Circuit parameters are obtained from the standard impedances and time constants by an iterative process outlined in the appendix. Where the treatment of these standard machine impedances and time constants is not mathematically reducible to the rotor network defined in Fig. 1 and TABLE I, the result will differ.

***TABLE 1:** Rotor circuit parameters for transient SSR studies*

| Parameter | D-axis | Q-axis |
|---|---|---|
| **$377R_f$** | 0.53 | 5.3 |
| **$X_f$** | 0.062 | 0.326 |
| **$377R_k$** | 1.54 | 3.1 |
| **$X_k$** | 0.0055 | 0.095 |
| **$X_a$** | 1.66 | 1.58 |
| **$X_L$** | 0.13 | 0.13 |

***TABLE 2:** Generator impedances and time constants*

| Parameter | Value |
|---|---|
| **$X_d$** | 1.79 pu |
| **$X_d'$** | 0.169 pu |
| **$X_d''$** | 0.135 pu |
| **$X_L$** | 0.13 pu |
| **$X_q$** | 1.71 pu |
| **$X_q'$** | 0.228 pu |
| **$X_q''$** | 0.200 pu |
| **$T_{do}'$** | 4.3 s |
| **$T_{do}''$** | 0.032 s |
| **$T_{qo}'$** | 0.85 s |
| **$T_{qo}''$** | 0.05 s |
| **$R_1$** | 0.0 |

Table III shows the inertias and spring constants for the spring mass model. Inertia is expressed in terms of the inertia constant H based on rated kVA. The base torque is that required at synchronous speed to deliver mechanical power in kilowatts equal to the rated (base) kVA value. Base angle is 377 radians, the angle of shaft rotation in one second (the base time). The spring constant K is given in per unit where base spring constant is defined as base torque divided by base angle. The simple second order torque equation in this system of units is:

$$T(pu) = 2H\ddot{\theta} + D\dot{\theta} + K\theta$$

The spring constant is also given in per unit torque per radian. For transient studies, the mechanical damping is assumed to be zero.

$$X_d = X_L + X_{ad} \qquad (1)$$

$$X_q = X_L + X_{aq} \qquad (2)$$

$$\frac{1}{X_d''-X_L} = \frac{1}{X_{fd}} + \frac{1}{X_{kd}} + \frac{1}{X_{ad}} \qquad (3)$$

$$\frac{1}{X_q''-X_L} = \frac{1}{X_{fq}} + \frac{1}{X_{kq}} + \frac{1}{X_{aq}} \qquad (4)$$

$$0 = \frac{1}{X_{fd}-377T_{do}'R_{fd}} + \frac{1}{X_{kd}-377T_{do}'R_{kd}} + \frac{1}{X_{ad}} \qquad (5)$$

$$0 = \frac{1}{X_{fq}-377T_{qo}'R_{fq}} + \frac{1}{X_{kq}-377T_{qo}'R_{kq}} + \frac{1}{X_{aq}} \qquad (6)$$

$$0 = \frac{1}{X_{fd}-377T_{do}''R_{fd}} + \frac{1}{X_{kd}-377T_{do}''R_{kd}} + \frac{1}{X_{ad}} \qquad (7)$$

***Figure 1:** Rotor model for transient study*

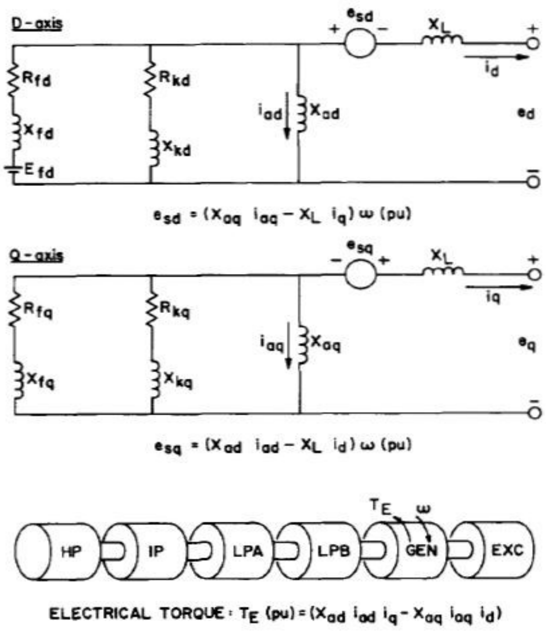

***TABLE 3:*** *Rotor spring mass parameters*

| Mass | Shaft | Inertia H(sec) | Spring Constant K (pu) | pu Torque/rad |
|---|---|---|---|---|
| **HP** | | 0.092897 | | |
| | HP-IP | | 7,277 | 19.303 |
| **IP** | | 0.155589 | | |
| | IP-LPA | | 13,168 | 34.929 |
| **LPA** | | 0.858670 | | |
| | LPA-LPB | | 19,618 | 52.038 |
| **LPB** | | 0.884215 | | |
| | LPB-GEN | | 26,713 | 70.858 |
| **GEN** | | 0.868495 | | |
| | GEN-EXC | | 1,064 | 2.822 |
| **EXC** | | 0.0342165 | | |

## 3. SIMULATION MODEL AND RESULTS

Field Voltage of Synchronous machine held at the same value

Mech. Torque of Synchronous machine held at the initial value

Multimass enabled at time = 1.4 sec. The input allows the multimass to be enabled only when the machine is active. The multimass is initialized with smoothed value of electrical torque from the machine model.

***FIGURE 1:*** *Shows the Simulation Model for the Study of SSR in PSCAD/EMTDC.*

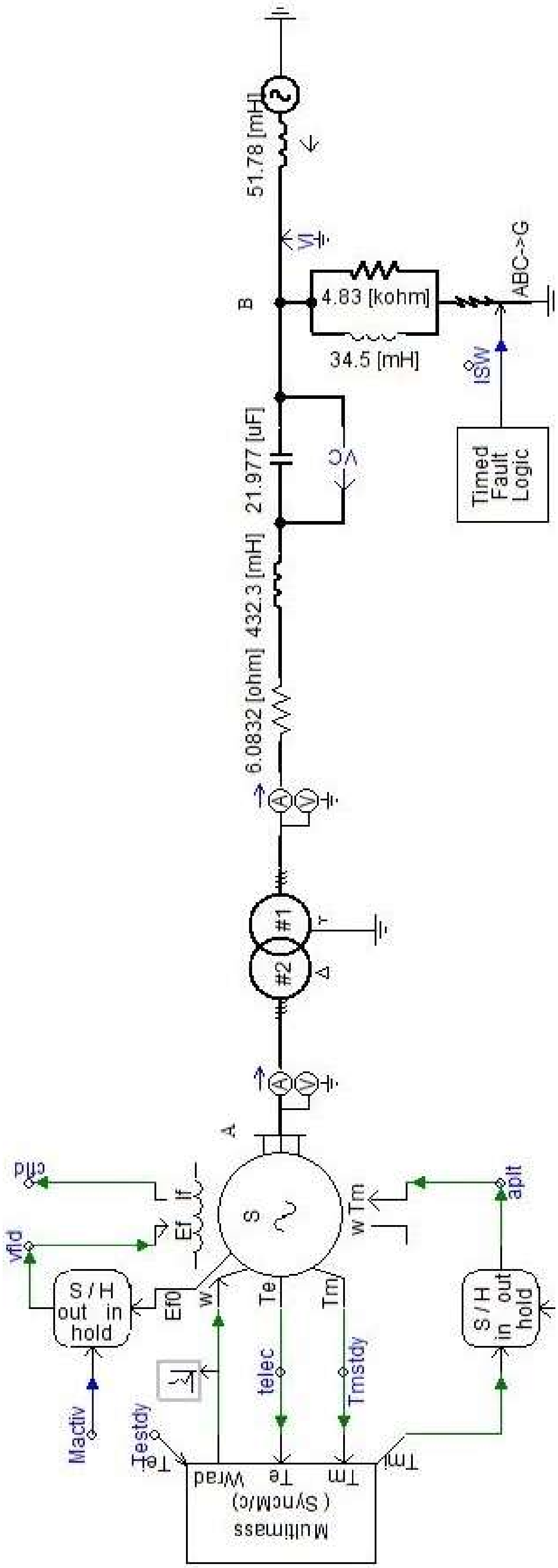


***FIGURE 2:*** *Simulated system in PSCAD/EMTDC*

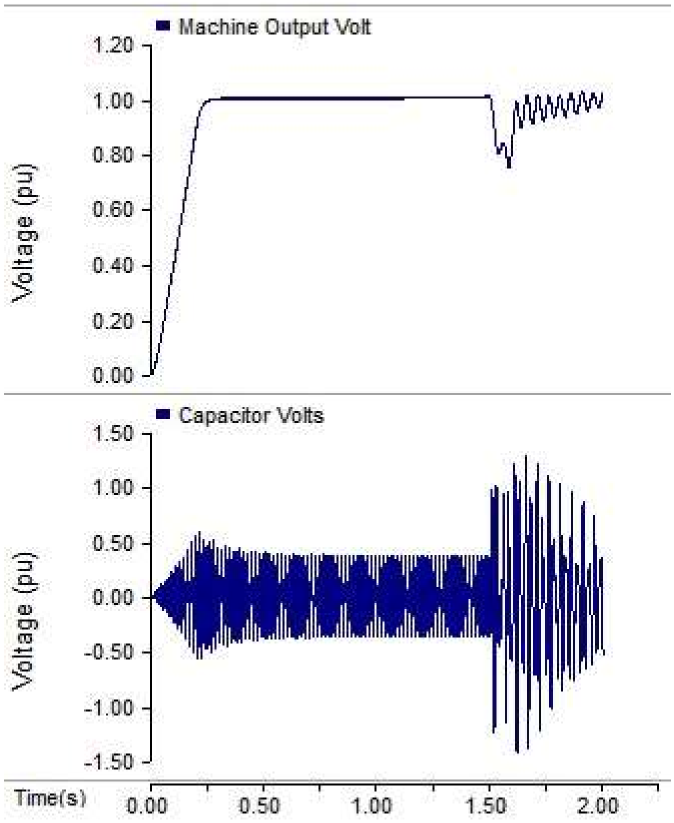


***FIGURE 3:*** *Machine and capacitor o/p voltage*

TABLE VI shows the minimum additional information required to specify a transient case. Study results should show at least the following as a function of time:

a. Generator phase currents
b. Phase voltages on bus A (see Fig.1)
c. Capacitor voltages

d. Generator rotor speed deviation
e. Electrical torque
f. Shaft torque for each shaft section

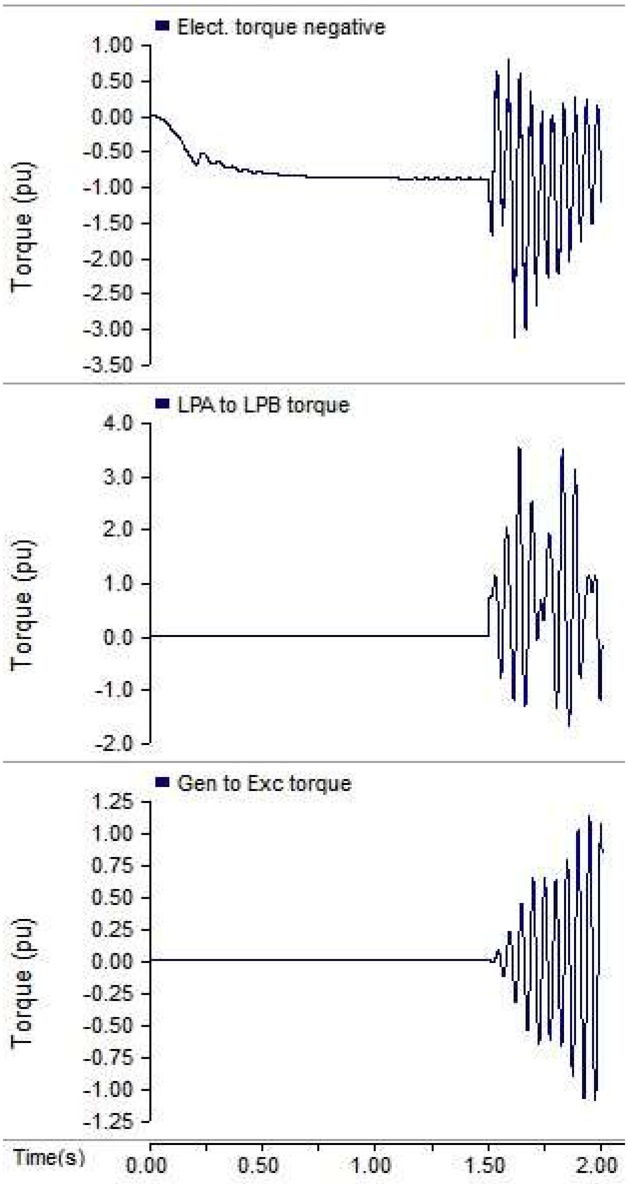


***FIGURE 4:*** *Response curve for transient case 1-T (Diff. torque)*

For case 1-T, $X_c$ is tuned to approximately 40 hertz both during and after the fault to excite the second torsional mode. The fault impedance $X_F$ has been adjusted to produce a capacitor transient voltage approaching the lower gap setting during the fault. A fault duration of .075seconds (four and one-half cycles at 60 hertz) was chosen to produce a notching the generator power envelope lasting three half cycles of the rotor second torsional frequency. This notch is intended to increase the shaft torsional response.

***TABLE 6:*** *Transient case description*

| Parameter | Value |
|---|---|
| Generator power output Po | 0.9 pu |
| Generator power factor PF | 0.9 (lagging) |
| Fault reactance $X_F$ (L-G) | 0.04 pu |
| Fault location | B |
| Type of fault | LLL-G |
| Prefault phase voltage | $V_a = 0$ |
| Clear 1$^{st}$ phase i=0 | 0.075 s after fault |
| Clear 2$^{nd}$ phase | next current zero |
| Clear 3$^{rd}$ phase | next current zero |
| Capacitor reactance $X_c$ | 0.371 pu |

## 4. CONCLUSION

Simple models and transient test cases have been presented for the study of sub-synchronous resonance. The generator model is successfully simulated using PSCAD/EMTDC. Authors are presently working on different cases of SSR.

## ACKNOWLEDGEMENT

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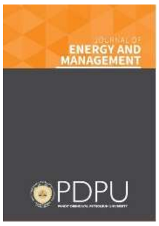


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# CHANGING ENERGY DYNAMICS IN EUROPE

**Nirav Modh**

**KEYWORDS**

Europe, Power Market, Nuclear phase-out, Renewables progress

**ABSTRACT:** The newly emerging energy game and changing trends in Europe going to influence the energy map of the world. The volatility of power & gas market has opened new opportunities for midstream companies in one way while the low oil & commodity prices has put same companies in situation to renegotiate their long term oil-gas contracts with supplier. The entry of new technologies and advancement in renewable sector has shifted whole portfolio mix for many power generation companies.

The current paper shall elaborate changing government policies and various factors affecting the energy business in Europe and hedging strategy of major energy-utility companies (mainly utility & midstream sector). Based on secondary research, interviews and discussions with the key personalities of energy sector, the paper also studies the dynamics from the perspective of the world energy market. The study shall be helpful to understand developed and mature energy market and provide good learning base for emerging economies like India.

## 1. INTRODUCTION

On the fine sunny Sunday of 16th June, 2013, power market of Germany witnessed very strange thing. The retail power was available at negative €100 per MWH. It means power generation companies were forced to pay the grid- keepers to take their electricity. It happened as the demand was suddenly bottomed up and electricity price went to lowest. Between 2pm and 3pm, renewable sources like solar and wind pumped around 28.9 GW of power, much above than expectation. The grid at that time was not able to handle more than 46 GW unless becoming unstable. At the peak, total generation was over 50 GW; so prices fell suddenly to encourage generation cut and safeguard the grid from overcapacity.

At that time, the major sources of power generation respectively were nuclear, coal, gas and renewables which were throwing electricity into grid. The power plants based on nuclear fuel or brown coal are designed such way that cannot easily switched off to reduce production, while the energy coming from solar and wind power is unrestricted. So the load of adjustment fell on gas-fired and hard-coal power plants, whose output plunged to only about 10% of full load capacity.

Such event is an example of complex problem faced by mature and developed energy market such in Europe opposite to market of power-scarce regions of developing countries. It is also a small-scale version of the challenges affecting European market-Germany in particular where renewable sources of energy are becoming more important and regulatory policies forcing energy industries to change traditional way of operating.

European energy market is into developed and mature stage having all infrastructure facility with suitable trading and distribution mechanism. For developing countries, on one hand energy market which is currently into nascent stage with lot of demand faces issues like poor infrastructure, availability & supply problems, on other hand European market faces major challenges due to changing govt. regulations, decreasing demand and geopolitical issues.

European market, which pioneered in CO2 emission trading, is undergoing a profound transformation with energy transition coinciding with technological advancement and regulatory changes due to commitment of reducing greenhouse gas emissions by 40% below 1990 levels by 2030. Nuclear phase out is another major challenge initiated by German government. Security of gas supply is also raise concern in current hostile environment between Russia and Ukraine.

As demand of power consumption stagnates, utility companies in Europe continue to be in hot water. Energy business revenues are directly linked to the demand for consumable energy. Final Energy Consumption (FEC) remained growing between 1990 and 2009. But after 2010 FEC levels has declined from earlier 20 years which is clearly not good sign for energy-utility companies. (Final energy consumption-FEC is defined as the total energy that reaches the end-users for consumption which include individuals, households, agriculture and industry).

The perfect indication is their stock prices which are also crashing like anything. Once considered the quintessential safe stocks and good investment bet, now no more attracting investors. Such energy-utility companies are now undergoing big restructuring as they respond to regulatory changes, demand fluctuations, price volatility and new energy trends. Such development has forced some utility companies to break down their business units into different entities to separate loss-making unit from profit making business. Fully-integrated* energy companies are selling their hydrocarbon and upstream assets to focus on one business and remain profitable. More effort is given to trading and midstream business to become more efficient. They have also started investing heavily in renewables apart from their traditional business.

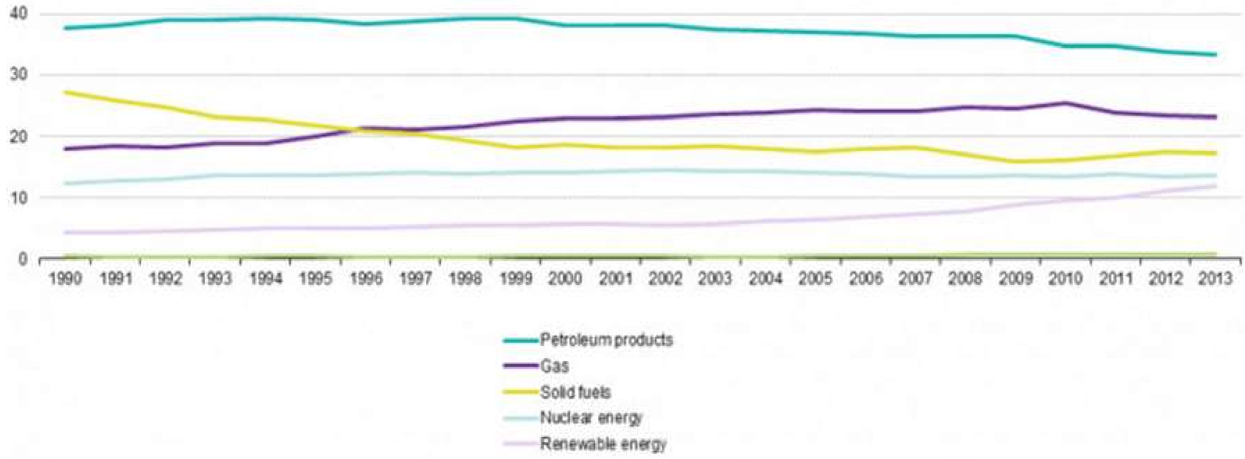
My research would analyze such factors in detail and also focus on changing strategy of energy-utility companies. The main epicenter of study would be Germany and European Union energy & utility business with little attention to other countries and upstream companies.

## 2. EUROPEAN ENERGY MIX

The energy industry involves the production and sale of energy, including crud exploration, refining and distribution. In broad terms, the energy sector comprises the petroleum industry-oil & gas, logistics & refining companies and the power utility industry including electricity generation, distribution and sales. As petroleum industry is categorized into upstream, midstream and downstream same way the utility company could be also categorized based on type of electricity generation such as coal based, nuclear based, gas based and slowly but steadily increasing renewable base.

European Union countries comprise only 2.8% of Global petroleum production which is not sufficient to fulfill its total energy demand. Since early 2000, crude oil production in Europe has been continuous dropped and it also missed out new fracturing boom unlike US. It is importing Petroleum products from other countries. In such condition, the major chunk of European demand is fulfilled by Gas supply through

Russian originated pipelines, internal coal reserves and nuclear based power plants. Total energy mix in European countries is as shown in below image.




*Source: http://www.mining.com, Gross Inland consumption EU-28- Source)*

Renewables have steadily increased in consumption since the 2000, and as a result the amount of electricity driven by renewables was around 12% higher in 2014-15 than it was in 1990. The energy source that has seen the least fluctuations in total usage for energy is nuclear energy. Until now its usage in power and other source as energy has remained steady. But now this trend is also going to change.

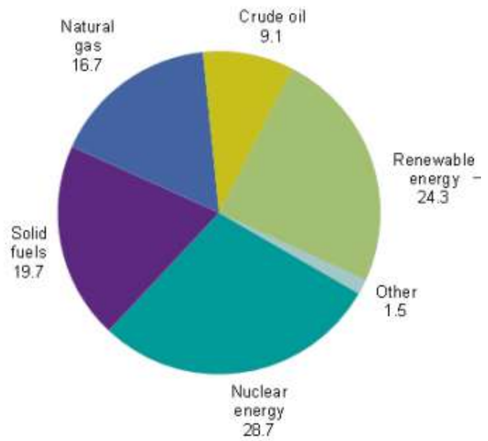
Consumption of gas is also an exciting story. Natural gas has been used more prominently in recent years as it became regarded as more environmentally friendly clean fuel than other fossil alternatives. However, as Europe is trying to reduce its dependence on Russian gas, leading to decline in its consumption in recent time for overall energy need including electricity.

The European Environmental Agency (EEA) measures final energy consumption-FEC and finds that the transport sector is responsible for around 32% of total energy consumption, households 26.2%, industry 25.6%, services 13.5% and agriculture 2.9% of total FEC in 2015. *(Source: EEA).*

## 3. ELECTRICITY GENERATION

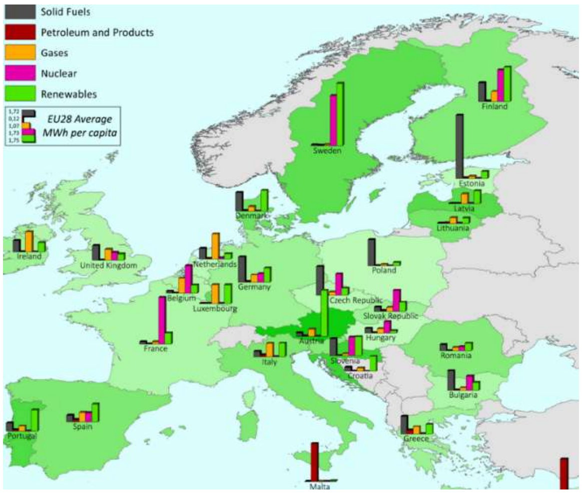
Traditionally, electricity generation in Europe is mainly based on Nuclear, Natural Gas and Coal (Solid Fuels). The major European countries highly depend on nuclear power for more than one-quarter of its electricity, and a higher proportion of base-load power. Break-up for energy generation in European Union countries based on type of fuel is shown in Figure 1.

***FIGURE 1:*** *Energy generation in European Union countries based on type of fuel*




*(Source-http://ec.europa.eu/eurostat/statistics)*

***FIGURE 2:** Europe's electricity consumption by country and fuel type*




*(Source: INFOGRAPHIC)*

Some outliners in Europe are countries like Estonia, Malta, Cyprus. Estonia is the only European country that relies heavily on solid fuels, with 86.6% of its energy needs met this fuel type, where shale gas is also considered part of solid fuels. Malta and Cyprus depends on petroleum products, which account for 98.3% and 92.4% of consumption respectively. They are small island-nations with little populations and resources to pursue big infrastructure spending on things like nuclear power plants. They simply import what they need, which allows them flexibility.

France is the biggest user of nuclear power, with 74% of consumption coming from that source. Belgium, Hungary, and Slovakia have more than half of their power coming from nuclear. Austria uses the most renewable energy with 80%. That said, the vast majority of this comes from hydro, where Austria uses its mountainous terrain to its advantage.

Germany is one of the largest consumers of energy in world and the highest in Europe. Due to abandon reserve of coal conventionally, almost one quarter of electricity in Germany produced based on coal. Germany is the 5$^{th}$ largest consumer of oil in the world. Russia, Norway, and the United Kingdom are the largest exporters of oil to Germany. Germany is also the third-largest consumer of natural gas in the world. Almost 39% of Germany's natural gas comes via pipeline from Russia.

Because of its rich coal deposits it has a long tradition of fuelling its economy with coal. It still is one of the top five consumers of coal in the world, even though it has started closing out domestic coal mining. Germany has the largest market of electricity in deregulated and mature European market. Nuclear power in Germany accounted for 16% of national electricity supply in 2015, compared to 23% in 2010 thanks to German government policy of nuclear plant phase out by 2022.

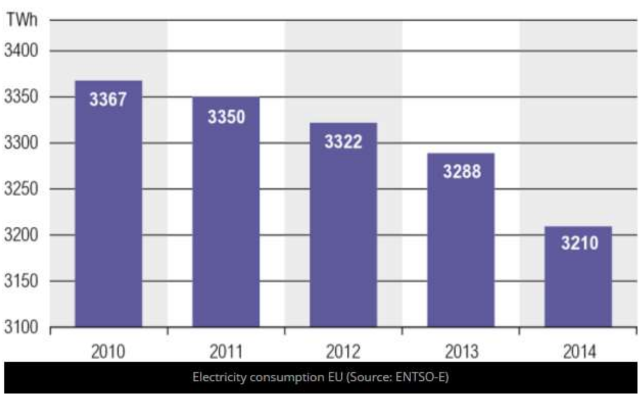
## 4. ELECTRICITY MARKET OF EUROPE

The European power market is continuously experiencing substantial changes with changing time. In 1990, the United Kingdom was the first country in Europe to liberalize its electricity market and set the example for other European nations for change in power dynamics that had driven EU liberalization and indirectly forced for unbundling of electricity market. Over the time, many steps were taken for achieving this aim by EU authority. In Germany also, with the passage of the energy law of 2005, the electricity market undertook an additional reform after the reform of 1998 which was initiated by the European Union (EU). Electricity generation, transmission and pricing were subjected to the new regulation; the wholesale market made advancement in the whole EU and the prices on the Exchange such as European Energy Exchange (EEX) became deciding factor.

In Europe, at present around 260-Million European customers are connected to electricity distribution grids. Around 2000 electricity distribution companies employing 2,00,000 people across the EU are responsible for providing a reliable and quality of supply to their customers. The German electricity market is the largest within the EU. It is connected to all neighbouring countries and in the way of achieving single power market within EU, there are considerable power flows have started between countries. The technical integration of the central European network is managed by the Transmission Service Organizations (TSOs) long before the liberalization in Europe. The supply-demand through grid management is done by Distribution System Operators (DSOs) and Transmission System Operators (TSOs). They are jointly in charge of maintaining security of supply and providing quality service of electricity in the grid system throughout the Europe. (Figure Source: Wikipedia, Transmission Grid Operator Network in German.


The top ten power companies in Europe are EdF, RWE, E.ON, Enel, GdF Suez, Vattenfall, Iberdrola, CEZ, EnBW and PGE – which make up around 80% of the electricity through direct or indirect subsidiaries. The total electricity consumption in the EU Countries was 3.21 million GWh in 2014-15 — which is the third consecutive fall in output from earlier years.

***FIGURE 4:*** *Electricity consumption in Europe union*




Presently, The European Union countries have unanimously set an ambitious goal of reducing its greenhouse gas emissions by 40% by year 2030 with strong policy framework. This will require lot more investment in renewable sector than present one with additional resources for wind and solar generation as well as measured policies to deal with the fluctuating & not-so-regular capacity offered by such renewables. The integration of national power systems into a single European system would provide huge benefits in levelling such fluctuations, enabling the whole power market to further increase its reliance on renewables. In this changing market Current utility companies and other market participants are facing challenges as expected for adapting to the new environment, but it is very important for them to sustain in this wave by adopting new ways.

## 5. CHANGING ENERGY DYNAMICS AND MAJOR CHALLENGES

It is apparent from the aforementioned historical data that energy consumption from traditional sources is declining in Europe. The Energy Information Administration projects that while the upward consumption of electricity growth is guaranteed over the long run, the medium to short-term direction of the market would remain uncertain. European electricity market is poorly hurt by changing regulatory policies, low electricity prices, overcapacity due to slow growth in Europe and renewable energy development. Wholesale electricity prices have dropped by around 30% and continue to decrease in EU markets. Power companies today can hardly bear their variable costs with present electricity-market model. No energy company is able to invest more in building new production capacity. This decline in pricing and sluggishness in retail consumption directly impact business revenues of all energy companies. While decreasing Oil & Gas prices has put upstream European companies like BP in difficult situation, falling power consumption demand has affected bottom line of utility companies as well. Fully-integrated energy companies also finding them in hot water situation. Either they are restructuring their business or selling out their assets.

Amid such decreasing demand, traditional utility companies are trailing behind due to the availability of alternate energy sources like renewable energy. Business myopia of such traditional energy companies to foray into emerging trends and changing market scenarios has failed them to diversify their business by enlarge till now. Currently none of the world's top 10 solar utility companies is from Europe. Two of the UK's big six and Germany's big four still remain heavily dependent on coal burning for their current revenues. i.e. RWE is facing difficulties to deal with its traditional portfolio of power generation which contain lignite (37% of the company's total power generation), coal (23%), gas (18%) and nuclear (15%) and only 4% renewables. This is one of the challenges faced by energy companies

Various other factors are as below.

## 6. CHANGING REGULATORY FRAMEWORK & REDESIGNING OF EU POWER MARKET

The European Union is on the edge of a full restructure of its electricity market including greater cross border trading of electricity. Market rules are supposed to change in accordance of the single decentralized system where renewables and the consumer would be the king. Changing regulatory norms & market rules are becoming challenge for utility companies as they may face newly arising issues such as grid bottleneck, inter-connection blocks, guarantee of supply & fluctuating demand. Also they will have to come up with diverse connectivity criteria between various Transmission Service Organizations.

At present, the market participants are also facing the heat in the form of enormously augmented & stringent regulation. Initially in the form of EMIR (European Market Infrastructure Regulations) and now REMIT (Regulations on Energy Market Integrity & Transparency). Although the aim of these regulations is to bring more transparency, their initial effects are really challenging for companies in many ways. Firstly, to hedge against the market manipulation, extra burden and complication have been added for market contributors who have to increase risk management and report trades to authority in transparent manner. Furthermore, such stringent regulations have removed many speculative or financial players from the market and from the ownership of assets as well. The influence of such change has shifted liquidity and strength of market to trading & marketing entity rather power generators and had changed electricity market dynamics rapidly.

The reason EU countries have put their trust on a single power market is to expand wholesale electricity competition among all market participants & electricity provider, with the aim of achieving lower electricity prices and providing cheap power to customers through more efficient use of resources in Europe. In many European countries, wholesale generation & even distribution markets are controlled by a single supplier. In such situation power supplying utility company would be at risk and have to change their current business model by diversifying in other geography.

## 7. NUCLEAR PHASE OUT POLICY BY VARIOUS EUROPEAN GOVERNMENT

In 2011, after the Fukushima disaster in Japan many European countries started reducing dependency on Nuclear Power. Germany has already initiated process of decommissioning all nuclear power plants under its long-held policy of 2002 for phasing out all reactors by 2022. Eight of the Seventeen operating reactors in Germany were permanently shut down till now and gradual phase-out of nine remaining nuclear power plants is under way. Belgium is also following it. Spain has cut down its plan to add any more nuclear based power plant. Even France, the home of many nuclear giants, has announced plan to reduce drastically its dependency on atomic energy.

Almost all major European utility company owns nuclear power plants across the Europe. Until last decade all of them were running to generate electricity based on nuclear power with heavy investment across the Europe. Now they all have to shut down such plant with additional cost of decommissioning them. The situation is like someone has robbed all assets and asking cost of doing that. Almost one quarter of revenue generation source is being taken away from major utility companies.

## 8. REGULATIONS TO LIMIT LIGNITE MINING AND CO2 EMISSION

Coal is categorized into hard coal (Lignite/Anthracite based) and soft coal (Bituminous based). Hard coal power generation is major source of CO2 emission and pollution. Having huge reserves of hard coal almost all countries in Europe till now produced large chunk of power based on it. But commitment to reduce emission under earlier Kyoto protocol and recent COP21-Copenhagen conference various European countries are forcing energy companies to reduce such environment polluting power generation.

In Germany, in an effort to cut power-sector emissions, Economic Affairs and Energy ministry, in March 2015 proposed that old, lignite coal based electricity plants have to pay a levy when they exceed a certain CO2 emissions level. Also government is mulling to ban on Lignite mining. Although such proposal led to fierce opposition as coal industry employs many people around the Europe and most energy companies majorly dependent on Coal for power generation. But growing momentum and strict government norms are forcing utility companies to find alternative as soon as possible.

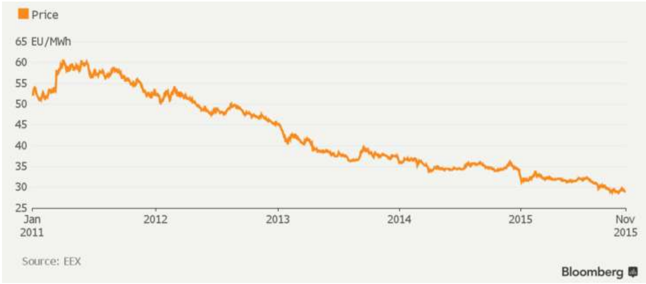
After nuclear thrust this one is another blow to energy companies. It's like someone is asking to fight war without carrying main weapons. Coal and nuclear being main source of power generation for many energy producing companies till now are finding themselves nowhere on the ground. As the rightly said by CEO of RWE

*"Debates such as the one over lignite make RWE look like a football team that has been forced onto the back foot and robbed of its ability to play a free-flowing game"*

## 9. DECREASING ELECTRICITY DEMAND AND PRICES

In first sense, reducing oil & gas price should benefit the power generation companies. But the situation in Europe is totally different, along with decreasing commodity prices, demand of power is also reducing and technological advancement with more availability of power than actual need spurring low price of electricity. Excess supply plus depressed demand equals lower prices. Electricity prices have fallen from over €80 per MWh at peak hours in Germany in 2008 to around €30-40 per MWh now.

***FIGURE 5:*** *Electricity price*




Another jolt has come from less cold winter from last few years have also decreased seasonal demand in Europe. Smart technology advancement is making retail users more efficient to save their electricity usage. Still the cost of production is not that much decreasing in line which has created critical condition for them to survive.

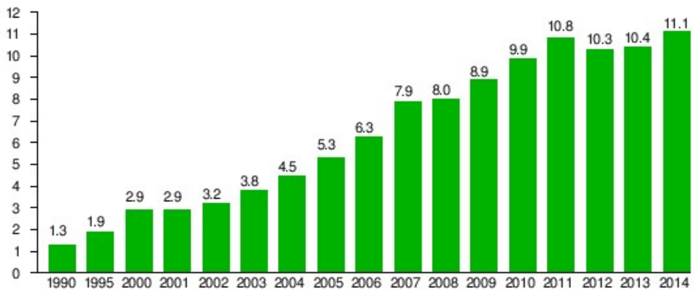
## 10. INCREASING CONSENSUS FOR USE OF RENEWABLES

Climate change has become one of the burning issues across the Europe. People in masses take out procession against nuclear and coal based power plant and supporting cause of saving environment which has forced government to promote the use of renewables for electricity generation. Drastic reduction in PV cell used for solar power has made the solar electricity cheaper. In the absence of nuclear and coal, various European countries are considering renewables as the best option to fill the void and power generation gap.

Such steps are putting traditional power generation companies in fierce competition against newly renewable based power generation companies. Additionally, increased opposition from environmental organizations and the general public against fossil fuel usage is putting such companies in more pressure.

Germany has planned to generate 70-80% of its electricity from renewable power by 2050, as part of efforts to combat climate change. Subsidies for renewables have increased power generation, and depressed wholesale electricity prices, and this has damaged the profitability of the utilities' coal and gas-fired power stations.

***FIGURE 6:*** *Renewables as a percentage of primary energy consumption in Germany*



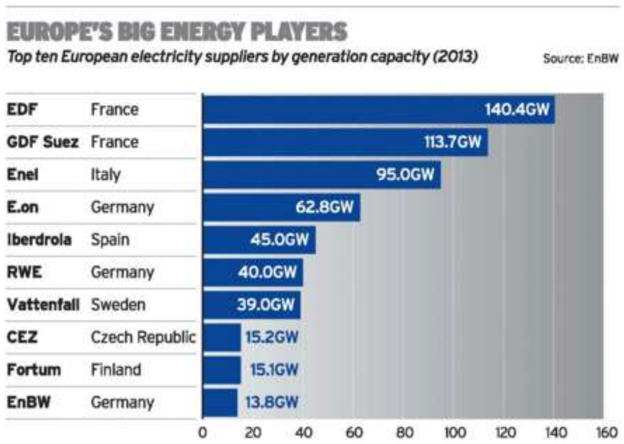

## 11. GEOPOLITICAL ISSUES

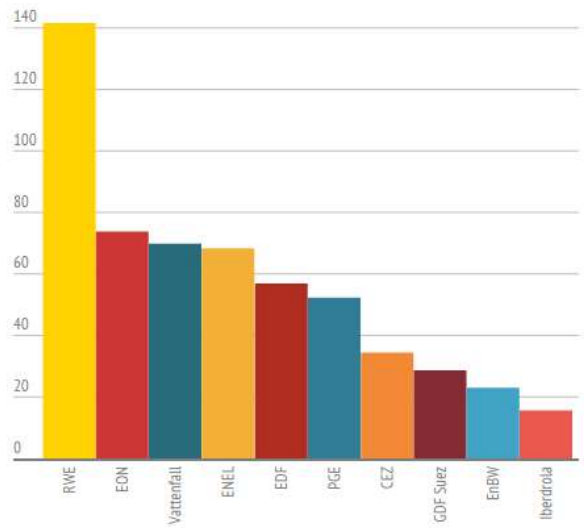
The strained relationship between European Union and Russia due to ongoing Ukraine crisis has worsened situation for European power companies whose gas based power plant depends on Russian originated Gas Pipelines. This geopolitical issue has made painfully obvious how Germany and other EU nations are dependent on Russian natural gas. There are other alternatives like LNG for supplying the natural gas, but they all come at additional price and may further increase production cost of electricity.

## 12. UTILITY COMPANIES AND THEIR HEDGING STRATEGIES

The value of power generation assets is getting down by billions of euros amid a plunge in wholesale power prices and a bleak future for fossil fuels. One of the top five European energy companies and Germany's largest EON SE posted its biggest net loss of €3.16 billion for 2014. Another Power major RWE posted net loss of loss of €2.8 billion earlier year. Their profit from conventional power plants has also reduced by 42%.

The other companies which were able to diversify early hedged themselves from overall loss but their traditional margins are shrinking to the lowest. Areva part of French Electricity giant EDF- reported a loss of about 4.9 billion euros ($5.6 billion) for 2014.



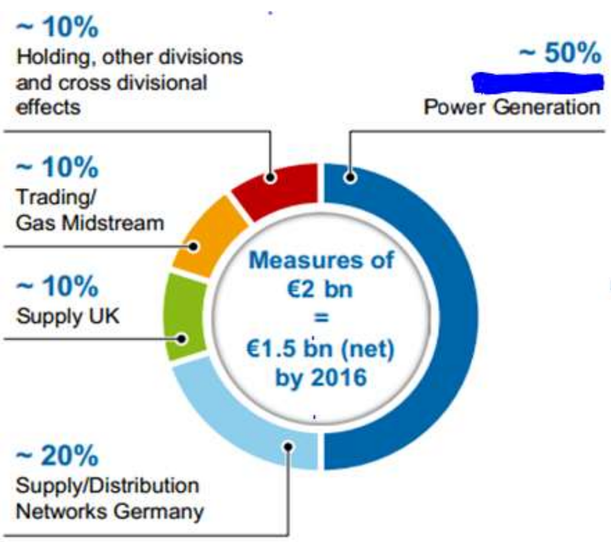

*Coal based Power generation of various utility companies in Europe (Source: - [http://www.greenpeace.org.uk/](http://www.greenpeace.org.uk/))*

It's high requirement for such energy companies to think alternative to survive them in changing energy market. Fossil fuels which is still used by many companies for major power generation may lead nowhere to them and they have to invest in renewables as timely need.

## 13. CHALLENGES BRING NEW OPPORTUNITIES- A WAY AHEAD

To combat against all odds, European energy companies are restructuring their business model, changing their portfolio mix, making their midstream & trading business more efficient and investing in renewables & new technology.

First of all they become more focused and sold of upstream assets to concentrate on one business. Secondly they structurally regrouped their non-core functions by following of operational excellence programs. Also they chose to diversify their portfolios outside the European countries and outside the power generation business such as trading and midstream in order to become less dependent on reality of the declining energy demand.




*Source: RWE website*

Energy companies have known well now that the business model which has worked well for them around 100 years may not last any longer. Europe's major energy companies are responding in different ways to the new challenges. Germany's EON has decided to split renewable business from conventional activities, whereas CEZ of the Czech Republic is reinforcing its focus on purely clean conventional generation. France's EDF has set asset management partnership with investors to finance its renewable business. RWE also recently introduced radical changes in its energy policy by unveiling plans to spin off its operations focused on renewable power, electricity distribution and retail sales. The group has proposed the creation of a separate listed company and splitting its business is similar to plans by its rival company Eon, which highlights Germany & Europe's energy transition phase.

As the RWE's Head of Innovation Inken Braunschmidt says "We want to be the Uber for energy" RWE recently invested in one of the world's largest solar power company Conergy and planning to invest around one billion euros in renewable energy in the next three years through direct or indirect mode. Apart from it, RWE is optimizing its midstream business. As shown in figure is RWE's plan for revenue generation for next year as they are focusing more on trading business which seems too lucrative in volatile market condition. Presenting RWE's results recently, CEO Peter Terium said: *"In our retail business, we will focus on developing our product and service offerings to existing and new customers. Alternative supply models and technological advances in the areas of smart metering and home automation will become increasingly important to win and retain customers"* (Source:-from Interview with Energy Post).

A market shift is now occurring in European energy and it is impacting everyone involved. Focus on ETRM (Energy trading & Risk Management), big data and smart technology in European power sector is set to bring changes dramatically. The future for European energy is going to be about optimizing assets; not just generating assets.

## 14. CONCLUSION

Amid falling end-user consumption, the energy business in Europe is expected to remain choppy at least in near term. The situation may worsen further if factors such as financial turmoil, currency challenges, efficiency improvements and a continued migration to renewables with stringent government norms. If relation with Russia further deteriorates then it would be double jolt for most European energy companies who has contract with Russian Gazprom for supply of Gas. Utility companies, especially those which are dependent on traditional sources like fossil fuels and nuclear power are expected to feel the heat of government policy.

Diversification into renewables is critical for long-term sustainability for these European energy business houses. Where there are challenges there are new opportunity as well. A key success factor for growth in the long-run will be to align business in government interests. Regulators and governments have also to play their role and establish rule enabling the market to evolve from a liberalized market to a managed market with opportunity of growth.

The energy companies of many other countries and continents are far from such situation and heavily investing in Nuclear and Coal but for sustainable growth diversification in renewables would be wiser step to survive in long run. The mix-portfolio structure is supported throughout the organization and ensures a long term sustainable position.

One thing is clear that every country would need lot of energy to satisfy hunger of their growing economy- be it European continent or any other in the world. When the economic downturn will start to disappear, the net demand for power may increase again. The companies who able to survive in current challenging environment would be dark horse in coming future. It’s all about adjusting with time and streamlining according to situation!

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# DO MSMEs PRACTICE ENERGY CONSERVATION PRINCIPLE: A CASE OF GUJARAT

**Yogesh C. Joshi, Kaushal Kishore**

**KEYWORDS**
Energy Conservation, Energy Policy and Practices, Energy Conservation Act, 2001, Micro, Small & Medium Enterprises (MSMEs)

**ABSTRACT:** The present paper attempts to study the current policy framework of Government in India and specifically in Gujarat with regard to energy conservation practices among MSMEs. In context of the present policy environment, it attempts to study measures adopted by various selected MSMEs in different districts in the state of Gujarat. The paper attempts to study the extent of various energy conservation practices adopted by MSMEs in Gujarat to be more efficient and competitive. The results are the outcomes of extensive qualitative research, as researchers conducted survey with the help of structure questionnaire with 53 MSMEs. The study is on energy conservation that is why; researchers intentionally used information available on website of Ministry of Power, Government of India on several occasions and put up detailed discussion in the body of paper. Additionally, various research papers, articles, news articles, reports from several organizations were broadly used to make it comprehensive study.

## 1. INTRODUCTION

The Indian economy is poised for higher economic growth rate in years to come. However this can be realized if overall efficiency is increased across all the sectors in the economy. The advancement in energy conservation and improvement in energy efficiency practices are going to play an important role in furthering productivity and efficiency in resource utilization in the economy. These improvements need to be embraced in all the sectors of the economy. Thus, primary, secondary as well as tertiary sectors require improvements in efficiency and productivity. Imbibing and institutionalizing energy conservation practices by an organization continuously helps a great deal in improving efficiency of resource utilization and reducing cost.

Small and medium scale foundry industry is vital in the Indian industries and would keep on playing an important part in the Indian economy later on (Patange & Khond, 2016).In order to sustain growth with employment generation, it is imperative that manufacturing activities get a fillip in the economy. The government of India has kept an ambitious target of increasing manufacturing production to 25 per cent of GDP instead of 16 per cent of GDP at present (Sathyadevi & Nisha, 2016). If India has to achieve this target of production in manufacturing sector then MSMEs will have to contribute significantly to this. The growth and extent of success of MSMEs will depend largely on how successfully and efficiently energy conservation practices are adopted and implemented by them among other measures of cutting cost and increasing productivity.

The issue related to energy conservation is creating a different mind-set amongst the MSMEs also. The present paper attempts to study the current policy framework of Government in India and specifically in Gujarat with regard to energy conservation practices among MSMEs. In context of the present policy environment, it attempts to study measures adopted by various selected MSMEs in different districts in the state of Gujarat.

## 2. SIGNIFICANCE OF MSMEs

Nearly 13 million such enterprises, spread all over India, produce over 40 per cent of the country's manufacturing output and employ an estimated 40 million people (SDC, 2010).MSMEs not only play crucial role in providing large employment opportunities at comparatively lower capital cost than large industries but also help in industrialization of rural and backward areas, thereby, reducing regional imbalances, assuring more equitable distribution of national income and wealth while providing employment in rural and backward areas of the economy(KPMG & CII, 2015).

The micro and small enterprises are unorganized and lack sufficient resources to develop and use clean and energy efficient technologies. With little access to new or improved technologies, they continue to use low efficiency technologies resulting in wastage of fuels and poor working conditions (SDC, 2010).The MSMEs in India contribute 8 per cent to its GDP, creating 100 million jobs through the 46 million units from the rural and the urban areas across of the Country. They also contribute to 90 per cent of the total Industrial output and 45 per cent of the Manufacturing output of India and come out with 6000+ products across the spectrum. MSMEs are credited in contributing to 36 per cent of the Total Value of exports from the Country and the sector has recorded a constant year on year growth of over 10 per cent thereby making this sector as the backbone of Country's economy (KPMG & CII, 2015).

Small-and medium-scale industries (SMI) industries are found in all major manufacturing sub-sectors (food processing (tea and desiccated coconut), textile, foundry, brick and ceramic, etc. and constitute about 85 per cent of the total number of manufacturing establishments in Asia. SMI also considered as engines for economic growth and development and contributes in employment generation (Visvanathan & Kumar, 1991) (Thiruchelvam, Kumar, & Visvanathan, 2003). India's GDP is expected to touch 8.5 per cent, with the country likely to be a USD 5 trillion economy by 2025. The MSME opportunity is to develop entrepreneurship and support growth led by innovation over the next decade by significantly increasing the share of MSME contribution to GDP from the current 8 per cent to 15 per cent by 2020 ;generate employment levels to the extent of 50 per cent of the overall employment, more than doubling the current MSME workforce of 106 million across agricultural, manufacturing and services sectors; and increasing the share of MSME contribution across key public and private industry sectors fulfilling increasing domestic demand, growth in exports, indigenization and import substitution (KPMG & CII, 2015).

Considering all facts and figures, it clearly indicates that MSMEs have been contributing a in the Indian economy for long and the need of the hour is that contribution should reach to the next level to make India as manufacturing hub in days to come.

## 3. MSME SCENARIO IN GUJARAT

Gujarat has registered an impressive industrial development since its formation as a separate state in 1960. The industrial sector at present comprises of over 1200 large industries and over 4,00,000 micro, small and medium industries. As per the results of the Annual Survey of Industry (ASI), 2009-10 carried out by the Central Statistical Organization (CSO), Gujarat accounts for 18 per cent of fixed capital investment, 17.22 per cent of gross output and 15.20 per cent of net value added in industrial sector in India (Solanki, 2013). Thus, Gujarat has large number of MSMEs.However, there is little indication of acceptance of increase in energy conservation and increased energy efficiency among MSME sector. This can be attributed to mainly three reasons, first the limited time available to the entrepreneur to identifycontract and finance energy efficiency opportunities in addition to the many other tasks that call forhis time; secondly the limited availability of local service providers who can support entrepreneurs in projectdevelopment, financing & implementation; and thirdly, a complete lack of investment in thedevelopment and deployment of new energy-efficient technologies that are suitable for MSMEs and canbe adopted easily by such players in a seamless manner(Himanshu & Dhingra, 2015).The MSMEs being located in nook and corners of the country, lack awareness regarding various technological advancements in energy conservation practices. The efforts by government are half hearted and inadequate to help and aid MSMEs in provision of finance, make them aware of advancement of technology including that of energy conservation practices, which help them, become efficient and match the best internationally.Thus, it is imperative that energy productivity enhancement processes have to be standardized anddemonstrated so as to enable MSMEs to adopt them without much hassles and difficulty. This will mean that transaction costs are minimized and efficiency be maximised for MSMEs. This will lead to greater profitability for entrepreneurs, local service providers, technology suppliers and financial institutions facilitatingfurther adoption of such technologies. However, in India and Gujarat as well, adoption and deployment of such energy efficient technologies and conservation practices has been very less specially among MSMEs due to a variety of constraints faced by them.

## 4. POLICY FRAMEWORK FOR ENERGY CONSERVATION

Indian industry has not paid much attention to energy savings. The high-energy consumption in the Indian industries is due to three main reasons, the foremost as the most of the manufacturing units still depend on old machinery, secondly; the cost of machine is higher as compared to European / U.S standards and last but not the least; uncertainty about the long-term growth of the particular industrial sector(Matani, 2013).

The majority of Small and Medium Enterprises SMEs have confidence in their own production technologies and do not believe in investing onenergy efficient and environment saving techniques (E3ST) as it involves incurring additional cost and entreprenures do not want to take any risk in matters unknown to them.Energy efficiency and environment protection have a low priority as compared to expansion for SME even though the project viability may be sound.(Thiruchelvam, Kumar, & Visvanathan, 2003).Any effort made to conserve energy not only reduces cost of production for an enterprise but also leaves more energy for other economic activities in the country. It therefore allows whole of the economy to operate more efficiently. With economic development it is obvious that energy demand is bound to rise during coming years and decades. The primary energy demand in India has grown from about 450 million tons of oil equivalent (toe) in 2000 to about 770 million toe in 2012. This is expected to increase to about 1250 (estimated by International Energy Agency) to 1500 (estimated in the Integrated Energy Policy Report) million toe in 2030. This increase in energy demand in India is driven by a number of factors, like increasing incomes and economic growth which leads to higher demand for energy in the form of lighting, cooking, space cooling, mobility, industrial production, office automation, household demand, greater electrification of rural areas, etc. (MoP, GOI, 2016).

This likely future increase in energy demand is also owing to the current very low level of energy supply in India: the average annual energy supply in India in 2011 was only 0.6 toe per capita; whereas the global average has been 1.88 toe per capita. It may also be noted that no country in the world has been able to achieve a Human Development Index of 0.9 or more without an annual energy supply of at least 4 toe per capita. Consequently, there is a large latent demand for energy services that needs to be fulfilled in order for people to have reasonable incomes and a decent quality of life (MoP, 2016)

India is a signatory to various international conventions and treaties related to energy conservations and environment protection. Accordingly efforts are being made in India to adhere to its international obligations through formulation of appropriate policy and its implementation. In pursuance of this the

Government of India has undertaken a two pronged strategy to fulfil the energy demand needs of its citizens while ensuring check in CO2 emissions, so that the global emissions do not lead to an irreversible damage to the earth system. On one hand, the government is gradually promoting greater use of renewable energy in the form of energy mix like solar and wind and selectively promoting advanced and more sophisticated technologies for coal based power plants. On the other hand, efficient use of energy management practices through various innovative policy measure initiatives under the overall ambit of Energy Conservation Act 2001(MoP, 2016).

The Energy Conservation Act (EC Act) was enacted in 2001 with the goal of reducing energy intensity of Indian economy. Bureau of Energy Efficiency (BEE) was set up as the statutory body on 1st March 2002 at the centre for facilitating implementation of this Energy Conservation Act. This Act provides for establishing regulations for first, standards and labelling of equipment and appliances, second, energy conservation building codes for commercial buildings and third energy consumption norms for energy intensive industries. In addition, the Act orders and directs the Central Government and the Bureau of energy efficiency to take steps to facilitate and promote energy efficiency in all sectors of the economy. The Act also directs states to designate agencies for implementing the Act and promote energy efficiency in each of the state. The EC Act (MoP, 2016) was amended in 2010 and the principal changes brought about to the Act are as below:

Firstly, it states that the Central Government may issue the energy savings certificate to designated consumers whose energy consumption is less than the prescribed norms and standards in accordance with the procedure, secondly, the designated consumer whose energy consumption is more than the prescribed norms and standards shall be required and entitled to purchase energy savings certificate to comply with prescribed norms and standards, thirdly, the Central Government may, in consultation with the Bureau of energy conservation, prescribe the value of per metric ton of oil equivalent of energy consumed, fourthly, Commercial buildings which are having a connected load of 100 kW or contract demand of 120 kVA and above come under the purview of ECBC under EC Act.

Ministry of Power, through Bureau of Energy Efficiency (BEE), has initiated a number of energy efficiency initiatives in the areas of household lighting, commercial buildings, standards and labelling of appliances, demand side management in agriculture/municipalities, SME's and large industries including the initiation of the process for development of energy consumption norms for industrial sub sectors, capacity building of SDA's etc. The target of energy savings against these schemes during the XI plan period was kept 10,000 MW of avoided generation capacity. These initiatives have resulted in an avoided capacity generation of 10836 MW during the XI plan period (MoP, 2016).

The Government of India has taken many initiatives as a result of enactment of EC Act in 2001 and its amendment in the year 2010. Various steps taken include scheme to promote energy conservation and energy efficiency include standards and labelling, energy conservation and building codes (ECBC), demand side management scheme- for agriculture, municipalities, capacity building for electricity distribution companies (DISCOMs) and energy efficiency in small and medium enterprises, strengthening institutional capacity of states-strengthening of state designated agency (SDAs), contribution to state energy conservation fund (SECF) scheme, school education programme, human resource development (HRD) and national mission for enhanced energy efficiency (NMEEE) (MoP, 2016).

During the 11th Plan period institutional and regulatory infrastructure has been created in the country. In order to implement NMEEE a framework was prepared after extensive stakeholders consultation and considering their view points, with relevant Ministries of Government of India, Central Electricity Regulatory Commission (CERC), State Governments, Industry associations such as Federation of Indian Chambers of Commerce and Industry (FICCI), Confederation of Indian Industry (CII), and other stakeholders like independent experts from academia such as IITs, research organizations, public and private financial institutions, NGOs etc. The NMEEE spelt out four initiatives to enhance energy efficiency in energy intensive industries like perform achieve and trade (PAT), market transformation for energy efficiency (MTEE), energy efficiency financing platform (EEFP) and framework for energy efficient economic development (FEEED). Under these programmes and schemes energy efficient initiatives and solutions have been implemented to affect all sectors of the economy. These are likely to bring about all round improvement in energy efficiency and conservation practices in the economy (MoP, 2016).

The government has setup a Bureau of Energy Efficiency under Energy Conservation Act of 2001. It was established on March 1st 2001 with objectives to reduce energy intensity in various sectors in the economy, to create awareness with regard to energy conservation, to provide professional certification and accreditation to various entities and to give its expert inputs and facilitate formulation of effective energy efficiency policy in the country. The functions as provided in the act include recommending the Government regarding energy consumption standards, to prescribe guidelines for energy conservation in buildings, to create awareness on energy conservation and disseminate information for efficient use of energy and its conservation among various users and stakeholders, to promote research and development in the field of energy conservation, to develop testing and certification procedures related to efficient energy use and conservation for various sectors. Further it is entrusted to formulate and facilitate implementation of pilot projects and promote use of energy efficient equipment, processes, devices and systems. The Bureau of Energy Efficiency acts as a nodal agency and organization to achieve desired objectives related to energy conservation in the economy. The Bureau is also responsible and entrusted with the task of promoting innovation, provide financial assistance to the institutes, maintain a list of accredited energy auditors, specify qualifications for the accredited energy auditors, specify manner and intervals of energy audit, specify certification procedure for energy managers, prepare educational curriculum for institutions and implement international co-operation programs among various institutions to coordinate efforts in energy conservation most efficiently(BEE, 2015)(MoP, 2016).

To encourage the energy efficient technologies and operational practices in SME sectors in India, BEE has initiated the energy efficiency interventions in selected 25 SMEs clusters during the XI plan. A study was conducted to assess energy use and technology gap at unit level, development of the cluster specific energy efficiency manuals, preparation of Detailed Project Reports (DPRs) on energy efficient technologies and capacity building and knowledge enhancement of man-force involved in SMEs. During the XII plan, implementations of 100 technology demonstration projects in 5 SME sectors are envisaged to facilitate large scale replication (BEE, 2015).

Hence, beginning of 21st century marked some important institutional setup coming into being in India for addressing issues of energy efficiency and conservation in various sectors and economic activity. Many crucial amendments have been brought about in the year 2010 as well, indicating seriousness of efforts undertaken in India. However; institutional performance requires high degree of transparency and commitment to achieve the stated objectives.

## 5. ENERGY CONSERVATION PRACTICES IN MSMEs IN GUJARAT

Energy Conservation offers a practical means of achieving development goals. It enhances the international competitiveness of industry in world markets by reducing the cost of production (Singh & Sharma, 2012).Economic development needs energy but large-scale energy consumption leads to negative environmental impacts such as GHG emission, deforestation, loss of biodiversity, resource depletion, emissions to water and soil, and waste disposal. One option to minimize/eliminate these negative impacts is by the use of energy efficient and environmentally sound technologies (E3ST). Due to strong financial back up, large industries could easily adapt E3ST and benefit financially, SMI are still reluctant to adapt them due to their inherent characteristics and resistance to change (Thiruchelvam, Kumar, & Visvanathan, 2003).Energy conservation is a decentralized issue and largely depends on the individual unlike decisions of energy supply which are highly centralized (Singh & Sharma, 2012).

Rao. and Apparao (2012) study analyzed that the performance of MSMEs in recent decade and also examined that the financial obstacles faced by MSMEs. Financial obstacles of great concern to owners/mangers of MSMEs are as follows: namely; inability to obtain external financing, inability to obtain internal financing, insufficient capital, start-up costs, expensive raw materials, high wholesale price, large losses due to scrap rate, sabotage, breakage and crime, decline in sales volume, bad debts and write offs, heavy equipment and maintenance costs, government tax, Value added tax and customs duty, payroll, rent and utilities, transportation and petrol costs, high interest rates on loans, ability to meet financial obligation, insurance costs and delay in account receivables payment.

Kumar (2014) concluded that increasing number of MSMEs and their fixed assets will enhance their gross output if the government provides support such as infrastructure, skill development, technology up gradation, supplying low cost of capital and marketing facility. Expanding MSMEs will enhance employment, exports and GDP of the Indian economy. The Study analyzed that growth and performance of MSMEs in India. Researcher found that the contribution of MSMEs is increased from 5.77 percent in the year 2001-02 to 11 percent in 2010-11 and expected to increase to the extent of 22 percent in 2011-12 .Therefore MSMEs are facing stiff competition from global players and large scale domestic firms of India. The contribution of MSMEs is commendable and significant to the growth of Indian economy.

Afroz (2014) studied that the closely analyses the growth and development of the Indian MSME sector since opening of the economy in 1991. The study also looks into the present scenario of MSMEs and the challenges they faced like lending, marketing, and license raj issues. MSMEs as a major contributor towards growth of domestic economy and employment generation, should also obtained adequate support for its growth and development in terms of policy framework, incentives and other relevance aids and supports like providing good infrastructural facilities, developing various industrial parks and technology incubators under MSME cluster development programmes, creating networks of organisations which help to provide training to the skilled workforce to improve productivity, encourage entrepreneurship and competency in management, funding R&D investments, technology advancement may work for the betterment of the sector.

Das (2014) examined the performance of MSMEs in the development of socio-economic condition of rural poor. The study revealed that there is a continuous growth of number of MSME units. The growth story of these sectors enhances production, employment and exports of the state as well as in our country. The State Odisha inherent to its location, natural resources has tremendous potentialities to create ample opportunities in small businesses in various sectors. Entrepreneurship development is considered as a key factor to fight against unemployment, poverty and achieve overall socio-economic growth in our state. Last but not the least, growth rate of MSMEs is very good and healthy sign towards progress and prosperity of Odisha.

On the basis of the above mentioned literature, we propose to study the MSME, more specifically focussing on energy conservation.

## 6. METHODOLOGY

The energy efficiency and conservation efforts for sustainable development help a firm in adoption of best practices in business. Successful energy conservation will lead to reduction in cost and allow production process to be more efficient, thereby increasing profits for a firm. However, it is a general belief that MSMEs are reluctant and slow to adopt energy conservation practices due to a variety of reasons and constraints faced by them including lack of finance, lack of awareness regarding technological changes and other implementation related issues. An attempt has been made to study energy conservation practices adopted by MSMEs in Gujarat. A total of 53 firms were conveniently chosen for eliciting information on a variety of conservation practices adopted by these MSME firms from across industries and across districts of Gujarat. The distribution of firms according to size is as shown in table 1 below.

***TABLE 1:*** *Sample Distribution*

| Scale of Firm | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| **Medium** | 30 | 56.6 | 56.6 | 56.6 |
| **Small** | 14 | 26.4 | 26.4 | 83.0 |
| **Micro** | 9 | 17.0 | 17.0 | 100.0 |
| **Total** | 53 | 100.0 | 100.0 | |

## 7. RESULTS

The sample firms were asked regarding steps taken to protect and restore environment sustainability with products, process and activities during last years, e.g. measures to control pollution, install solar and LED lights etc. the responses are shown in table 2 below. It is clear from table that a large proportion of firms have always or usually taken steps for this purpose. Only a handful of firms are not taking steps for protecting environment sustainability. The top five measures adopted for this purpose by firms are detailed in table 3 below.

***TABLE 2:*** *Steps Taken to Protect Environment Sustainability*

| Frequency | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| **Always** | 31 | 58.5 | 58.5 | 58.5 |
| **Usually** | 16 | 30.2 | 30.2 | 88.7 |
| **About Half the time** | 4 | 7.5 | 7.5 | 96.2 |
| **Seldom** | 1 | 1.9 | 1.9 | 98.1 |
| **Never** | 1 | 1.9 | 1.9 | 100.0 |
| **Total** | 53 | 100.0 | 100.0 | |

***TABLE 3:*** *Measures Adopted for Sustainability by Firms*

| Measures | Responses | Percent of Firms | Percent of Response |
|---|---|---|---|
| **Tree Plantation** | 30 | 56.6 | 25.6 |
| **LED Lights and Energy efficient devices** | 17 | 32.1 | 14.5 |
| **Transport vehicle pollution reduction** | 25 | 47.2 | 21.4 |
| **save water and reduce polluting methods of Production** | 25 | 47.2 | 21.4 |
| **Safe disposal of solid and liquid waste** | 20 | 37.7 | 17.1 |
| **Total** | 117 | | 100.0 |

It can be discerned from table 3 above that almost 56 per cent firms undertook tree plantation as one of the step for promoting steps for sustainability, 47 per cent firms took steps for reduction in pollution from transport vehicles as well as save water and reduce polluting methods. A total of 20 firms constituting of thirty seven per cent of firms use safe disposal of solid and liquid waste while 32 per cent of the firm have been LED lights and energy efficient devices in their premises. Thus it can be inferred that various steps for sustainability are adopted by most of the firms although all the firms are not using all measures for sustainability of business and environment among selected MSMEs in Gujarat.

The need for energy conservation cannot be over emphasized for any organization, due to its obvious benefits in reduced cost for firm as well as for society as a whole. Further, energy conservation helps in sustainable development too. The energy conservation practices related to computers and equipment, adopted by sample firms in Gujarat are presented in table 4 below. A perusal of table 4 reveals that among selected MSMEs 38 per cent to 83 per cent firms adopt various energy conservation practices on their premises. There is therefore, a greater need for further widespread adoption of energy conservation related to computers and equipment among MSMEs in Gujarat.

The need for energy conservation cannot be over emphasized for any organization, due to its obvious benefits in reduced cost for firm as well as for society as a whole. Further, energy conservation helps in sustainable development too. The energy conservation practices related to computers and equipment, adopted by sample firms in Gujarat are presented in table 4 below. A perusal of table 4 reveals that among selected MSMEs 38 per cent to 83 per cent firms adopt various energy conservation practices on their premises. There is therefore, a greater need for further widespread adoption of energy conservation related to computers and equipment among MSMEs in Gujarat.

The sample firms were also probed for energy conservation practices adopted by them relating to heating and cooling procedures during production processes. The responses received from them are presented in table 5 below. A perusal of table 5 reveals that various energy conservation practices related to heating and cooling are adopted by selected firms to an extent of as high as 79 per cent firms and too low of 24 per cent of selected firms in Gujarat. This clearly indicates that practicing energy conservation related to heating and cooling is prevalent only to a limited extent only.

The table 6 below presents data on use of energy conservation practices in firms with regard to lighting in its plant and premises area. A perusal of table 6 reveals that lighting related energy conservation practices are being practiced by a maximum of 78 per cent firms and a lowest of 36 per cent firms among sample MSMEs in Gujarat. Use of daylight and skylight instead of electrical light is the practice most popular option exercised by firms. On the other hand, task lighting option is least popular amongfirms and only 36 per cent firm used it. Thus, in case of various steps for energy conservation for lighting purpose as well, overall, a majority of firms are found wanting in terms of adoption of such conservation practices.

The sample firms were further explored regarding other miscellaneous steps undertaken by them for energy conservation. The data pertaining to these other steps is given in following table 7. A perusal of table 7 shows that the firms are engaged in other energy conservation practices as well like safe disposable of recyclable material, switching power off of other appliances and specialty equipment in the firm and conserving water, etc. However, it is clear that a majority of MSMEs firms are partially and sparingly using energy conservation steps in their production process in Gujarat and only a small proportion of firms are found to be using these energy conservation practices to drive their business to greater efficiency, reduce cost, achieve faster growth and be competitive.

***Table 4:*** *Use of Energy Conservation Practices in Firms (Computers and Equipment)*

| Energy Conservation Practices | Responses | Percent of Response | Percent of Firms |
|---|---|---|---|
| Computer & Personal Items-Turn off all personal appliances including fans, radios and desk lamps | 39 | 34.5 | 83.0 |
| Turn off all office equipment including computers, monitors, printers, plotters, facsimile machines, shredders, typewriter and overhead task lights | 29 | 25.7 | 61.7 |
| Turn off all equipment in computer labs. if you can't turn off the whole computer, turn off the monitor and the printer | 18 | 15.9 | 38.3 |
| When purchasing any office equipment, be sure to consider energy star models that 'power down' after a specified period of inactivity | 27 | 23.9 | 57.4 |
| **Total** | **113** | **100.0** | |

***TABLE 5:*** *Use of Energy Conservation Practices in Firms (Heating and Cooling)*

| Energy Conservation Practices | Responses | Percent of Response | Percent of Firms |
|---|---|---|---|
| Set local thermostats to low or off, in case of a programmable thermostat and use it by setting an energy conservation code at optimum. | 15 | 17.0 | 30.6 |
| Manual control of thermostat, set the heating point to no greater than 68 degrees C/154 degree F and cooling to no less the 25 degrees C/78 degree F. | 12 | 13.6 | 24.5 |
| Keep windows and exterior doors closed in heated or air conditioned areas. | 39 | 44.3 | 79.6 |
| Portable electric heaters and fans not used, unless medically necessary or due to failure of the building heating, ventilation or air conditioning system. | 22 | 25.0 | 44.9 |
| **Total** | **88** | **100.0** | |

***TABLE 6:*** *Use of Energy Conservation Practices in Firms (Lighting)*

| Energy Conservation Practices | Responses | Percent of Response | Percent of Firms |
|---|---|---|---|
| Use day lighting from windows or skylights, instead of electrical lighting whenever possible. | 39 | 36.8 | 78.0 |
| Replace incandescent lamps with the lower watt compact fluorescent lamps whenever possible. Compact fluorescents (CF's) and LEDs help to reduce unwanted heat gain during hot summer months still provide equivalent lighting. | 22 | 20.8 | 44.0 |
| Try task lighting to reduce overhead lighting. | 18 | 17.0 | 36.0 |
| Turn off all unnecessary lights, including: overhead lighting, lighting in unoccupied rooms, equipment and storage areas. Reduce overhead lighting, decorative lighting, signage and other lighting inside and outside not necessary for security and safety. Maintain security and safety lighting at the lowest acceptable levels. | 27 | 25.5 | 54.0 |
| **Total** | **106** | **100.0** | |

***TABLE 7:** Use of Energy Conservation Practices in Firms (Miscellaneous)*

| | Responses | Percent of Response | Percent of Firms |
|---|---|---|---|
| Turn off all office and kitchen/lunch room appliances including copiers, printers, microwave, toaster ovens, and coffee pots every night and weekend. | 33 | 33.3 | 70.2 |
| Turn off all specialty equipment that will not be used over the weekend and holidays.<br>Use hot water sparingly. Conserve water. Turn off water taps when not in use. Don't use tap water for "single pass" cooling. | 33 | 33.3 | 70.2 |
| Recycling. Please dispose of recyclable materials to the appropriate recycling receptacles provided throughout the campus and building locations. | 23 | 23.2 | 48.9 |
| Please go to the recycling link on our Home page. | 10 | 10.1 | 21.3 |
| **Total** | **99** | **100.0** | |

## 8. DISCUSSION AND CONCLUSIONS

Successful implementation of energy conservation opportunities requires commitment of top management towards energy conservation, well defined programs and responsibilities of every stakeholder, availability of sufficient resources for planning and implementation of policies and strategies, utilization of latest techniques for operation and maintenance of machines and motors, pay back calculations and return on investment savings calculations and close interaction between top management, operating staff and maintenance staff (Matani, 2013). In a study and project by Swiss Agency for Development and Cooperation(SDC) suggested steps for lasting results and for disseminating new energy solutions are as generating trust, pooling expertise and talent; demonstrating economic viability and developing a host of complementing capabilities, services andInstruments; Encouraging replication, adaptation and innovation; creating an enabling environment (SDC, 2010). Energy conservation of course is the need of the hour as it has several advantages in terms of cost saving and environment friendly. Energy conservation can be nicely executed through energy audit as well.

Energy audit is vital tool in identifying and perusing a complete energy management program. A care full audit may give the industry an idea about managing energy at minimum cost (Patel & Panchal, 2015).Energy audit comprises of acquaintance with energy systems of the factory; information collection regarding energy utilization, production, etc. to base these energy balance; planning and execution of energy measurements; and information collection regarding the energy systems development to serve as a base for drawing up energy saving measure (Pathak, 1999)

The energy conservation practices are gaining importance in an era of globalization and competition. In order to remain efficient and socially accountable it is imperative for every firm to operate in a responsible manner. Keeping pace with international norms and need to be at par with other modern economies in India as well Energy Conservation act has come into being in the year 2001. This Act has been modified and amended in the year 2010 again to incorporate other required changes and fine tune it according to needs of Indian economy. In accordance with EC Act 2001, the required institutional and infrastructure changes in Gujarat has been undertaken to fulfill its objectives. However, it can be stated that a lot of efforts in terms of implementation of EC Act are required to be made to ensure that energy conservation is universally accepted and adopted by a majority of entities in the economy.

The study reveals that a considerable proportion of MSMEs are practicing energy conservation in one form or the other form in Gujarat, but at present they are practicing this only in a piecemeal and fragmented manner. Hence, in order to ensure that energy conservation becomes a norm and culture among producers in the country a lot of efforts are required to be undertaken on part of all the stakeholders.

## 9. LIMITATION AND SCOPE OF FUTURE STUDY

Any research is having certain restrictions which act as hindrance in carry out quality research work. This research is not untouched with obstacles. One of the limitations was to convince the MSMEs to cooperate in the research. Secondly, existing several obligations and protocols in the organization made authors to keep determination alive as competent authority at the organization were not available to respond, even after prior appointment. Such approach of the individual indeed delayed the overall research work.

The present study is based on only 53 MSMEs only, which is not as much of number of available MSMEs. Better sample size can be considered for the future course of study. Additionally, study can be conducted in other states of India which may include highly developed and underdeveloped state as overall practices adopted by MSMEs are highly influences by the state of the development.

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