



Engr. Nawaz Ahmad Virk (PhD)
DIRECTOR
SAARC ENERGY CENTRE



About SAARC Energy Centre

Energy cooperation is a driver for the SAARC process leading to durable peace in the region. SAARC Energy Centre has been created through Dhaka Declaration in 2005, as the Special Purpose Vehicle to realize the vision of SAARC leaders to establish an Energy Ring in South Asia. It started journey from 1st March 2006 in Islamabad. SAARC energy cooperation programme provides a major substantive element for economic prosperity of South Asia through meeting the energy

demand of the countries. SAARC Energy Centre is converting energy challenges into opportunities for development. It is the platform involving officials, experts, academia, environmentalists and NGOs to tap potentials of cooperation in energy sector including development of hydropower, renewable and alternative energy, promoting technology transfer, energy trade, energy conservation and efficiency improvement in the region.

Slogan:

Energy for Peace & Prosperity.

Vision:

Energy security for South Asia through development of indigenous, regional as well as Intra-regional resources by enhancing cooperation and optimal use of resources.

Mission:

Contribute as a regional Centre of Excellence on energy to fulfill the energy needs through sustainable and least cost energy solutions.

Goals:

1. Strengthen South Asia's capacity to collectively address global and regional energy issues.
2. Facilitate energy trade within the SAARC region, through the establishment of a regional interconnections and energy markets.
3. Promote the role of private sector in energy sector (i.e., production, transportation, trade, energy conservation).
4. Enhance regional human capital in energy sector.
5. Promote use of alternative and renewable energies/technologies in the region.
6. Induce the culture of energy conservation in the region.
7. Promote Transfer of Technology (ToT) in the energy sector in South Asia.
8. Contribute in providing regional energy data and information.
9. Undertake programs to achieve the above goals by approaching the Region and beyond.



Newsletter

Jan-Jun 2021

Editor-in-Chief:

Mehnaz Khurshid Gardezi (Ms.)

Concept & Design:

Mehnaz Khurshid Gardezi (Ms.)

Phone: +92 51 222 8802 & 4
+92 51 222 1937

Message from the Director SEC

Dear Readers,

Most of the SAARC region is suffering from long-prevailing poverty and associated socio-economic, health as well as environmental challenges. To counter these an important strategy would be to supply adequate and cheap energy to the masses and the industry. This essentially requires development of efficient, clean and sustainable energy sources for which collective and continued efforts at national and regional levels are needed.

In the SAARC region, deployment of an efficient, cost-effective, and clean energy system requires that the regional and national energy strategies must include, alongside the exploitation of conventional energy resources, the transition towards sustainable energy systems for reduction of harmful emissions and mitigation of climate-related calamities. Though challenging, transition to clean and sustainable energy is unavoidable to meet the future energy needs without damaging and compromising the environment of the region.

With cost-effective and sustainable energy, the region can stimulate its industrial sector for enhanced but low-cost production. This will increase national as well as individual income through enhanced employment opportunities.

The SAARC Energy Centre (SEC) has been mandated to work for Member States in devising effective policies and strategies for development of an efficient, clean and sustainable energy sector. Since its inception SEC has consistently contributed in the efforts of Member States for development of a clean and sustainable energy sector to achieve socio-economic uplift. The Centre pledges to continue its efforts and dedications to the Member States, utilizing its best available resources, expertise and skills in the field of energy.

My sincere appreciation for SEC team and especially Ms. Mehnaz Khurshid Gardezi, Editor-In-Chief of this issue towards bringing out this Biannual Volume 2021. Thank you and stay safe.



Engr. Nawaz Ahmad Virk (PhD)

SEC TEAM



Engr. Nawaz Ahmad Virk (PhD)
Director



Dr. Shoaib Ahmad
*Deputy Director
(Coord)*



Dr. Tanvir Ahmad
*Program Leader
(Technology Transfer)*



Ahsan Javed
*Research Fellow
(Renewable Energy)*



Ihsanullah Marwat
*Research Fellow
(Energy Efficiency)*



Umar Mukhtar
*Research Fellow
(Energy, Transport & Environment)*



Tula Ram Poudel
*Research Fellow
(Energy Transfer)*



Ahmad Talha
*Research Fellow
(Technology Transfer)*



Muhammad Ali Qureshi
(RF Power)



Mehnaz Khurshid Gardezi
Communication Specialist



Jahanzeb Hassan
Administrative Officer



Huma Robin
PS to Director SEC



Muhammad Saeed
Protocol Officer



Ammar Hassan
Computer Operation Officer



Farmanullah Marwat
Accounts Assistant



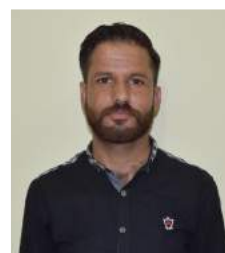
Abdul Wahab
Data Entry Operator



Khawaja Muhammad Awais
Administrative Assistant



Ajmad Ali
Support Staff



Naveed Qureshi
Support Staff

Video Conference to Disseminate “Action Plan for Electric Utilities of SAARC Countries to Introduce EV Charging Infrastructure”



SAARC Energy Centre (SEC) organized a Video Conference to Disseminate “Action Plan for Electric Utilities of SAARC Countries to Introduce EV Charging Infrastructure” on 28th January 2021.

SEC conducted a study in 2019 to coordinate with the selected electric utilities of the member states and facilitate them in formulating action plans for introducing EV charging infrastructure. This video conference aimed to disseminate the findings of that study, to get feedback from member states for value addition, and to build awareness among the Member States for a future transition towards the electric transport system.

Following important aspects were covered during the video conference:

- The long and medium-term vision and current investment outlook of the selected electric utility companies
- The mid to long-term action plan on the introduction of EV public charging infrastructure development.
- Technology options under consideration
- Potential sites for charging infrastructure deployment
- Investment outlay for potential deployment
- Provision of third-party private investment and operation of charging stations
- Business model/mode of payment for using charging infrastructure
- Commitment to carry out assessment studies for EV at an organizational level

Video Conference on “Assessment of Industry Readiness for Manufacturing of BEVs in SAARC”

SAARC Energy Centre (SEC) organized a Video Conference to Disseminate the Study on “Assessment of Industry Readiness for Manufacturing of Battery Electric Vehicles in SAARC Countries” on 2nd February 2021.

Battery Electric Vehicle (BEV) demand is rising globally. Buyers are mostly attracted to these vehicles based on several factors such as savings on fuel cost, low maintenance and robust performance. In addition, BEVs have a significant positive impact on energy and the environment. BEVs can assist in improving efficiency in electricity systems through storage and demand-response services. The use of BEVs can reduce local air pollution and the country’s share in global carbon emissions. It also helps in lower spending on fossil fuels which are, in case of most SAARC Member States, imported from abroad at the expense of precious foreign reserves. In this context SEC under its thematic area of “Programme on Successfully Implement Technology Transfer (POSIT)” conducted a study on “Assessment of Industry Readiness for Manufacturing of Battery Electric Vehicles” in FY-2019.



Video Conference to Disseminate Study on “Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries”



SAARC Energy Centre (SEC) conducted a dissemination video conference on 15th February 2021 for study report. “Energy Efficiency Improvements in Power Generation and Distribution Sectors of SAARC Countries” in 2020. The objective of this research study was to serve as a guideline for energy efficiency improvements in the power generation and distribution sectors of SAARC countries. The video conference aimed to disseminate the findings of the study, get feedback from Member States for value addition, and impress the importance of energy efficiency upon the participants from respective Member States.

The video conference covered, the following aspects of energy efficiency improvements in generation and distribution sectors:

- General overview of the state of power generation facilities and distribution systems of SAARC Member States.
- An empirical assessment of the opportunities of improvement in the generation of electricity and its distribution in SAARC Member States.
- Identification of low hanging fruits pertaining to energy efficiency in the power generation and distribution network: a roadmap for economically viable implementation of resource saving measures.
- Impact of the energy efficient practices uncovered during the study on the overall operation of the power sector.
- An overview of ways in which power sector regulators can facilitate the adoption of energy efficiency in the sector.

Webinar on “Techniques to Forecast Long-term Demand of Electricity for SAARC Member States”



SAARC Energy Centre (SEC) conducted a Webinar on “Techniques to Forecast Long-term Demand of Electricity for SAARC Member States”, which is aimed towards enhancing the general awareness and capacity of the professionals in the SAARC region. This webinar was knowledge sharing event which targeted at techniques, measures and interventions, which can contribute to better forecast of electricity demand in the SAARC Region.

This Webinar covered on the most pressing topics and case studies related to forecasting demand of electricity, with experts leading the discussions and presentations on proven best practices, cost-effective strategies, and innovative techniques.

Webinar on “Economic Dispatch and Unit Commitment Modelling Using PLEXOS® or Similar Software”



The electrical load of a power system is continuously changing throughout a day and its peak changes from one day to another. Given this ever-changing load, the power system operator schedules beforehand the start-up time of required generating units as well as time to connect them to the grid. Thus, economic dispatch and unit commitment are the key conundrums for a power system operator to solve optimally for ensuring economic and reliable power supply to consumers.

PLEXOS is an integrated optimization platform for electric power, water and gas systems developed by Energy Exemplar, currently in use in more than 62 countries. PLEXOS is a robust mathematical optimization tool which involves deterministic & stochastic techniques and can be used to solve the complex problems of economic dispatch and unit commitment. By training their professionals to optimize the economic dispatch, SAARC Member States can reap multiple benefits of economic dispatch such as reduced electricity costs; more efficient generation which in turn means better fuel utilization, lower fuel usage and reduced air emissions; increased operational reliability; and flexibility to incorporate policy targets.

SAARC Energy Centre conducted a webinar on “**Economic Dispatch and Unit Commitment Modelling using PLEXOS® or similar software**” on 5th March 2021. The objective of this webinar was to familiarise the participants on the application of PLEXOS® to economic dispatch problems for power systems of varying sizes, diverse generation sources and dispatch facilities.

Video Conference to Disseminate Study on “Technical Issues and Financial Viability of Net-Metering Mechanisms from the Perspective of Distribution Utilities”



SAARC Energy Centre (SEC) has conducted a Video Conference on 15th March 2021 for disseminating the findings of the study report on “**Technical Issues and Financial Viability of Net-Metering Mechanisms from the Perspective of Distribution Utilities**”.

The study was carried out in year 2020 by SEC. The study had thoroughly explored and discussed post net-metering financial and technical challenges faced by distribution utilities of SAARC, grid operators and other relevant stakeholders. The viable and proven solutions from other parts of the world to solving these challenges were also included in the study.

The video conference was attended by participants from Member States, representatives of Electric Regulators/ distribution Utilities, academia and private sector etc.

Webinar on “Intelligent Lighting Systems”



SAARC Energy Centre (SEC) organized a Webinar on “Intelligent Lighting Systems” on 25th March 2021.

The Webinar where experts of the lighting presented on smart lighting technologies, sensing and control strategies, benefits and potential energy savings of Intelligent Lighting Systems. They shared the history, latest development and market of Intelligent Lighting Systems. The objective of this webinar was to spread awareness among the people of South Asia about the use of intelligent lighting system for their comfort and wellbeing.

Video Confernece on Assessment of Wind & Solar Power Forecasting Techniques in SAARC Countries



Forecasting primarily helps reduce the uncertainty associated with power generated by Renewable Energy (RE) sources within a globally connected and complex atmosphere. The aim of reducing uncertainty finds myriad benefactors across all stakeholders in the power and energy sectors. This is especially true in the case of SAARC nations that are all at different stages on their distinct paths of growth and advancement of their power systems and markets. Consequently, forecasting systems in each of these countries are also at different stages of development. Nations such as India and Sri Lanka are more advanced in their preparedness for higher penetration of renewables compared whereas Afghanistan, Bhutan, Nepal and Maldives that are at nascent stages. Pakistan and Bangladesh find themselves in the middle of the spectrum with sectoral advancements taking shape in recent years.

To assess the status of wind and solar power forecasting, RE penetration, policy targets for RE additions and government plans for augmenting RE forecasting systems, SEC conducted a study on “Assessment of Wind and Solar Power Forecasting Techniques in SAARC Countries” in FY-2020. To get feedback from member states for value addition, and to build awareness among Member States, SEC organised “Assessment of Wind and Solar Power Forecasting Techniques in SAARC Countries”.

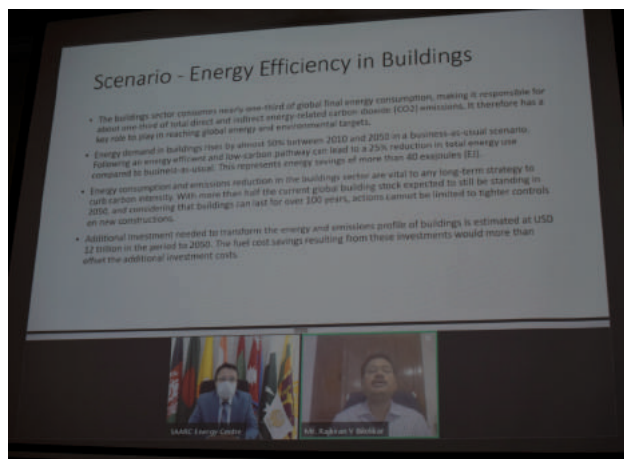
Video Conference on “Challenges in Financing of Utility Scale Clean Energy Project in SAARC Countries”



The energy sector of any country is critically important for its economic development and to improve the standard of living for its residents. Countries across the globe are engaged in several initiatives to achieve uninterrupted, affordable and clean energy supply for sustainable future. The world has entered an era where the nexus between energy and climate change is slowly becoming the focal point during the strategy and policy formation for energy sector interventions. On the similar lines, the SAARC member states have also witnessed transformations in its power systems and structures with a strategic thrust on promoting clean energy in past few years.

In order to understand the current investment environment, discover the challenges, and understand the required programs to mobilize funding for utility scale clean energy projects; aiming to enhance the availability of financial resources and to establish a conducive financial environment for deployment of utility scale clean energy projects in the SAARC member states SEC conducted a study on **“Challenges in Financing of Utility-Scale Clean Energy Projects in SAARC Countries”**. To get feedback from member states for value addition, and to build awareness among Member States, SEC organised.

Webinar on “Energy Audit of Residential and Commercial Buildings”



SAARC Energy Centre (SEC) organized a Webinar on **“Energy Audit of Residential and Commercial Buildings”** on 16th April 2021.

This webinar discussed Energy audit in residential and commercial buildings, Barriers in effective implementation of energy audit in SAARC nations and Latest trends and technologies used in building energy audits of buildings. The webinar was attended by officials from relevant Government departments of SAARC Member States. Research organizations, academia, associated industry and entrepreneurs were also present in the webinar.

Webinar on “Achieving Efficiency Improvements in Trucking Sector”



SAARC Energy Centre (SEC) organized a Webinar on “Achieving Efficiency Improvements in Trucking Sector” on 26th April, 2021.

Although freight trucks make up a relatively small percentage of the on-road vehicle fleet, they are responsible for a disproportionately large share of fuel consumption and greenhouse gas (GHG) emissions. Due to various factors including lack of truck efficiency, the logistics cost is very high in South Asia and ranges between 13-14 percent of GDP, as compared to 8 percent in the USA. There are wide range of proven technologies currently on the market that can increase the efficiency/mileage of these vehicles. This webinar aims to educate the professionals from SAARC region about advancements in the trucking sector with respect to improved efficiency, and it will provide an opportunity for the audience to engage with the experts of the heavy vehicle transport sector and to seek replies to their queries.

Following important aspects were covered during the webinar:

- Economics of the trucking sector
- Current scenario of the trucking sector in SAARC
- Drivers for efficiency improvements in the trucking sector
- Technological options and contemporary solutions
- Best regulatory, fiscal and policy tools for driving/promoting efficiency improvements in trucking sector



Webinar on “Use of Drones in Operation/ Maintenance of Power Transmission Lines”

SAARC Energy Centre (SEC) organized a Webinar to introduce and familiarize the professionals with those latest technologies which are used in the drone for inspection, operation & maintenance of power transmission lines in the SAARC Member States. This webinar was a knowledge dissemination event which shall including presentations from regional and international experts covering best practices, case studies and latest technologies employed by the electric utilities around the globe.

Video Conference to Disseminate Study on “Possible Uses of Crop Residue for Energy Generation Instead of Open Burning”



SAARC Energy Centre (SEC) organized a Video Conference to Disseminate Study on “Possible Uses of Crop Residue for Energy Generation Instead of Open Burning” on 24th May 2021.

Aim of the video conference was to disseminate findings of the study report among SAARC Member States and to seek their feedback. The research study “Possible Uses of Crop Residue for Energy Generation Instead of Open Burning”, evaluates the potential of crop residue available in SAARC region, for conversion into useful energy and to assess technological options with valid cost benefit analysis.

Major topics discussed during the video conference included; Overview of agriculture sector, prevalent disposal methods and technologies to generate energy from crop residue, Energy generation potential for Member States, Barriers and challenges for implementation and recommendations. The video conference was attended by officials from relevant government departments of SAARC Member States, research organizations, academia, associated industry and entrepreneur.

Webinar on “High Voltage Direct Current Transmission Systems”



SEC organized a webinar on “High Voltage Direct Current Transmission Systems” on 31st May 2021. The webinar facilitated learning with respect to the bulk power transmission through HVDC options with pertaining to its usage and application i.e., back-to-back interconnections and point-to-point connections. Experts from Hitachi ABB Power Grids shared their knowledge and experiences on the technical aspects of the HVDC systems and how such projects can be designed and managed.

The webinar was successful in achieving its overall objective of spreading awareness in the critical domain of High Voltage Transmission System among the professionals of SAARC Member States.

RECENT JOININGS

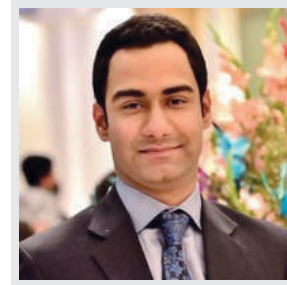


Engr. Nawaz Ahmad Virk (PhD)
Director SEC

Dr. Nawaz Ahmad holds PhD in Land and Water Resources Engineering (Geological Carbon Sequestration) and MSc in Sustainable Energy Engineering from KTH Royal Institute of Technology, Stockholm Sweden. He holds BSc in Mining Engineering from University of Engineering and Technology, Lahore.

He is an energy professional with over 20 years of experience in the energy sector. He has been serving Ministry of Energy (Petroleum Division), Government of Pakistan since 2002. Prior to joining Ministry of Energy, he served the private sector. At present he is looking after the affairs of LNG and LPG at the Ministry of Energy. His experience covers upstream, midstream, and downstream petroleum sector: technology, policy, regulation, and economics.

He owns transdisciplinary research skill set in the petroleum, power, and environment sectors: enhanced petroleum recovery, flare gas recovery, monetization of marginal and low-heating-value gas fields, LNG supply chain, virtual gas pipeline (LNG/CNG), sustainable and renewable energy, energy efficiency, waste-to-energy, district heating and cooling, waste heat recovery, energy modeling, desalination, CCS, climate change, GHG inventory, control of GHG emissions, environmental pollution, sustainability, contract management, energy and environmental economics, techno-economic analysis, policy, and regulation.



Muhammad Ali Qureshi
Research Fellow (Power)

Mr. Muhammad Ali Qureshi joined SAARC Energy Center (SEC), Islamabad in April 2021 as Research Fellow (Power). He received his bachelor degree in Engineering Sciences with majors in Semi-Conductors and Super Conducting Devices, Digital Controls Systems and Instrumentation from Ghulam Ishaq Khan Institute of Engineering Sciences and Technology (GIKI), Pakistan. He is a Certified Energy Auditor and Certified Energy Manager from Association of Energy Engineers (AEE), USA and a Project Management Professional from Project Management Institute (PMI), USA.

Mr. Ali is an experienced energy professional with over 10 years of diversified experience in Power Sector. He has worked with private sector and international development sector organizations. Prior to joining SEC, he was working with United Nations Industrial Development Organization (UNIDO) as National Expert RE & EE on GEF funded projects. During his tenure at UNIDO, he was involved in the development of the policy recommendations for promotion and uptake of RE and EE in industrial sector of Pakistan. Under the framework of GEF funded REEE project, he launched Energy Management System implementation and Energy System Optimization program in over 50 industries across Pakistan.

WORLD ENVIRONMENT DAY 2021



In preparation of the World Environment Day 2021, SEC team during plantation drive at schools and public spaces in Islamabad



Seeding by using by Drone Technology



In preparation of the World Environment Day 2021, SEC team during plantation drive at schools and public spaces in Islamabad



SEC team kicks off World Environment Day (June 5) activities



SEC steamers on different road junctions in Islamabad

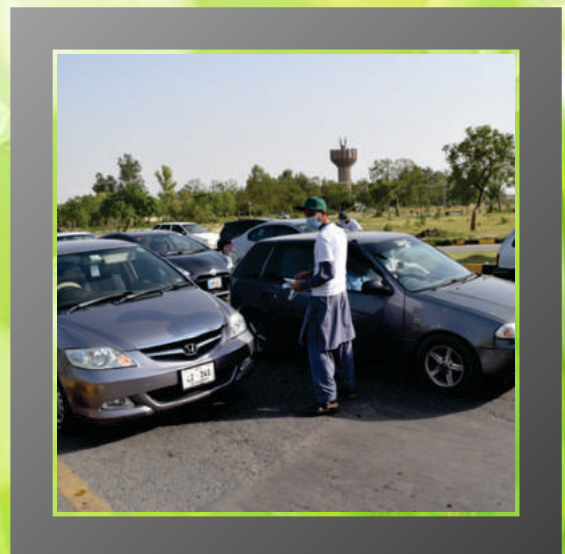
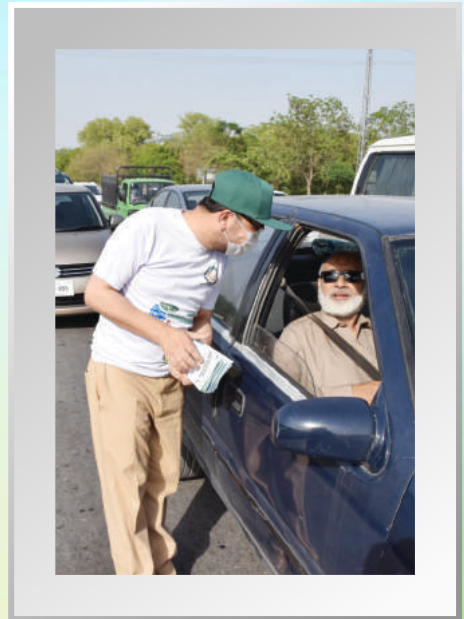
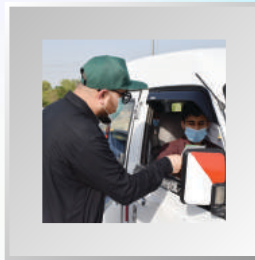


SEC professionals during environment related discussion on a TV Channel



SEC steamers on different road junctions in Islamabad

SEC team distributing environment related informative brochures to the public





Mr. Mohammad Naeem Malik, former Director SEC welcomes newly appointed Director SEC Engr. Nawaz Ahmad Virk



SEC welcomes new Director, Engr. Nawaz Ahmad Virk (PhD).



73rd National Day Celebrations of the Democratic Socialist Republic of Sri Lanka at SEC



SEC Professionals during a report launch ceremony of “Barriers and Drivers of Solar Prosumage (a case study of Pakistan)” at NEPRA Headquarter Islamabad.



SEC bids farewell to Mr. Mohammad Naeem Malik Former Director SEC





Dr. Nawaz Ahmad, Director (SEC) and team paid a courtesy call on Hon. Mr. Omar Ayub Khan, Federal Minister for Energy, Government of Pakistan. Hon. Federal Minister extended his full support to the Centre



SEC Professionals attended UNESCAP's "Third Session of the Committee on Energy" virtually from 24 to 26 February 2021

Ongoing Studies

“Economics of Transition to Euro-6 Fuel”

“Efficiency Enhancement and Solarization of Streetlights in SAARC Region”

“Mini grids and Access-to-Electricity in SAARC”

“Renewable Energy for Food Storage in SAARC Countries”

“Power Pricing for Cross-Border-Electricity-Trade in South Asia”

“Hand Book for Setting-up National Power Exchanges in SAARC”

Application of Shapely value based cooperative game approach to public charging infrastructure in South Asia

1. Introduction

Deployment of electric vehicles becomes viable for South Asia when power required to drive the electric vehicles comes from the economic, clean and indigenous resources such as renewable energy¹. One major concern for such deployment is to build the financially viable charging infrastructure. To build the efficient charging infrastructure, it requires to address various issues such as who should bear the cost, and how to achieve maximum cost saving. Many researches have been carried out to find the best cost sharing option among the stakeholders of electric vehicle industry. J.J Liu and S.L Cao have put forward the cost sharing method about the sharing mechanism of the value chain cooperation enterprise by using the Shapely value method of the game theory². Shapely value method provides win-win situation among the players with the most stable, lowest and reasonable cost sharing. The players may be a single party, a double party alliance, or a triangular party alliance. In this article, shapely value method of game theory that can be applicable for construction of charging piles in South Asian countries has been discussed.

2. Shapely Value Definition

The Shapely value was introduced by American mathematician and economist Lloyd Shapley. It is a solution concept used in game theory that involves fairly distributing both gains and costs to several players working in coalition. Shapely value primarily applies to the situations where the contributions of each actor are unequal, but each player works in cooperation with each other to obtain the gain or payoff.

In a coalitional game, let's say there is a set N (of n numbers of player) and we have introduced another variable 'v', that maps subsets of players to the real numbers i.e. $v : 2N \rightarrow R$ with $v(\emptyset)=0$, where \emptyset denotes the empty set and $v(S)$ is called the worth of coalition S , that

describes the total expected sum of payoffs the members in coalition. The amount that player i gets given a coalitional game (v, N) is³

$$\varphi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|! (n - |S| - 1)!}{n!} (v(S \cup \{i\}) - v(S))$$

where the sum extends over all subsets S of N not containing player i . When coalition is being formed one actor at a time then $(S \cup \{i\}) - (S)$ is a fair compensation with each actor demanding their contribution, and then for each actor take the average of this contribution over the possible different permutations in which the coalition can be formed.

3. Cost Sharing Strategy and Option by Stakeholders of Electrical Vehicle Industry

The nature and structure of perspective players or stakeholders in electric vehicle industry may vary from country to country in South Asia. However, the main players come from three broad categories: local governments, electric utilities and electric vehicle manufacturers. In those country where setting up of manufacturing facilities becomes costly and imported vehicle are used then landowners or existing petrol pump owners can be the part of coalition in place of manufacturers.

When only one player is involved in construction of charging piles, they will face many problems such as high cost of construction, long construction period and so on. The use of the cooperative game model can help them to solve the problems efficiently. If the local government is forming the coalition, its subsidy provided will be saved. In turn, it will invest in the charging piles. When vehicle manufactures are involved in building the charging piles then they have to pay the installation cost, the land lease, and operation and maintenance cost. Similarly, when electric supply company or grid operator make coalition, it will consider the cost of

generation and transmission of power which will be less than the tariff of electricity. Also, they get support from the government and the vehicles manufacturers on human and material resources to save cost and resources, and to enhance profitability in return. This coalition can speed up the construction process of charging piles and also improve the expansion of electric vehicles.

Hence, in three party's joint investment in the charging pile: they share less electricity tariff costs; they take advantage of land tax that can be considered as zero; and, electric supply companies can share the costs related to charging pile construction. These all gives and takes are considered while calculating the coalition game (v, N) as expressed in previous section. The cost shared by individual parties will be much less than they were constructing individually⁴.

4. Conclusion

South Asia is in initial stage of introducing the electric vehicles. Recently, only India is getting momentum and rest countries are still in planning and policy formulation phase. The use of game theory based on shapely value will provide an efficient way of sharing the cost in charging infrastructure for introducing massive electric vehicles and moving towards sustainable transportation.

¹SAARC Energy Center, *Infrastructure and enabling environment for road electric transport in SAARC Member States*, 2020

²J.J. Liu, S.L. Cao, *The game analysis of cost sharing in the construction of the charging pile alliance based on Shapley value*, 2015

³Wikipedia, Shapely Value

https://en.wikipedia.org/wiki/Shapley_value

⁴Cuiwei Li, Shiyu Ma, Yi Ren, Pinning Zhang, *Research on Financing Method of Public Charging Facilities Based on Cooperative Game*



Tula Ram Poudel
Research Fellow
(Energy Trade)
SAARC Energy Centre

RE Grid Integration Challenges

Wind and Solar generation both experience intermittency which is a combination of non-controllable variability, partial unpredictability and depends on the resources that are location dependent. These three aspects create distinct challenges to the grid operators and generation owners in integrating wind and solar generation.

Non Controllable Variability: Wind and Solar power generation output varies in a way that it cannot be controlled by the generation operators because wind speeds and sunlight may vary from time to time. Which eventually affects instantaneous output. This fluctuation in power output results in a need of additional power from the backup generators in order to balance the supply and demand gap on the grid on instantaneous basis and also for providing provision of ancillary services such as voltage support and frequency regulation.

Partial Unpredictability: Partial unpredictability refers to our inability to predict, with precision, whether the wind and sun will be generally available for energy production an hour or a day from now. This hour-to-day uncertainty is significant because grid operators manage majority of energy on the grid through “unit commitment”, the process of scheduling generation in advance, generally hours to a full day ahead of time, in order to meet the expected load. When actual production does not match the forecast, the grid operator must balance the difference.

Location Dependence: The best wind and solar resources are based in specific locations and, unlike coal, gas, oil or uranium, cannot be transported to a generation site that is grid optimal. Generation must be co-located with the resource itself, and often these locations are far from the places where the power will be ultimately used. New transmission capacity is often required to connect the wind and solar resources to the rest of the grid.

Recommendations to Grid Operators:

The intermittent nature of renewables and unpredictability of wind and solar resources makes it challenging for the grid operators to provide the base load energy through renewables. However, there are certain counter measures which can be taken by grid operators and RE plant operators in order to cope with RE grid integration challenges arising from intermittent nature of renewables.

One such challenge, as described earlier,

is the **variability** in the context of wind and solar resources and the fact that their output power is not constant. On the seconds to minutes' time scale, grid operators must deal with fluctuations in frequency and voltage on the transmission system that, if left unchecked, would damage the system as well as the equipment on it. To do so, operators may order generators to inject power (active or reactive) into the grid, not for sale to consumers, but in order to balance the actual and forecasted generation of power, which is necessary to maintain frequency and voltage on the grid.

As the RE penetration grows into the Grid it has become increasingly important that RE generation should play a greater role in helping to maintain system reliability and stability, and this may be increasingly required by interconnection standards. Technologies have been developed and are continuously improving at the generation unit, plant and plant cluster level to make RE generation more predictable, controllable and dispatchable, or in other words more grid-friendly. The advanced operational capabilities of wind generation units and solar photovoltaic inverters, they are now able to provide ancillary services such as primary frequency regulation, voltage/ Var control and regulation, fault ride through, active power control and curtailment, short circuit and current control. Grid operators can now draw support from wind and solar farms for voltage regulation through reactive power compensation and frequency regulation through pitch control mechanism of the wind turbines generator and automatic generation control (AGC). Through reactive power compensation, unnecessary voltage fluctuations can be controlled in transmission which can significantly reduce the line losses thus leading to major savings. RE power plants can also benefit from this if they are compensated monetarily for reactive power compensation running in voltage control mode. This can be a win-win situation for transmission and generation companies.

On the other hand, the partial unpredictability can also be controlled through **Advance Forecasting Technologies and Advance Unit Commitment (AUC)** techniques discussed under:

1. Advance Forecasting Techniques:

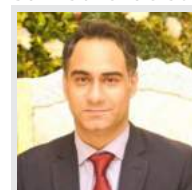
Wind and solar resource forecasting

predicts future energy output through numerical weather prediction models (NWPM) and statistical approaches. Resource forecasting is relatively new compared with system load forecasting, and it is not yet as accurate. Based on the available wind resource data and through utilizing advance forecasting tools, it is easier to perform the short, medium and long-time forecasting. The wind power plant operators can predict the energy outputs based on the forecasting techniques and tools available with a certain level of uncertainty.

Solar forecasting is relatively easier when compared to wind forecasting as resource data is available in addition to the metrological data and the sun paths which in turn can be used for prediction of Solar Plant output. Furthermore, following the same steps as described for wind can help grid operators to schedule generation in advance, generally hours to a full day ahead of time, in order to meet the expected load.

2. Advance Unit Commitment (AUC) Techniques:

Properly anticipating the wind and solar output levels through adequate forecasting techniques allows the grid operator to modify the scheduling of the other generators so as to optimally utilize all the assets under a grid operators' purview. The operators must, for example, ensure that adequate spinning and non-Spinning reserves are available not only to cover transmission line or generator outages but also to respond to the still unanticipated fluctuations in wind and solar output. Assisting the operator in this process is Advance Unit Commitment (AUC) methods which takes into account the stochastic nature of wind and solar generation and their relative concentration on the system in recommending the scheduling of other generation resources. The goal of Advance Unit Commitment is to cost effectively maintain sufficient flexibility on the system, such that the integration of RE resources neither exposes the system to unacceptable reliability risks nor over schedule the reserves in a way that unnecessarily burns the fuels and emit pollution.



Muhammad Ali Qureshi
Research Fellow (Power)
SAARC Energy Centre

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SAARC ENERGY CENTRE

697, St 43, Sector E-11/4 (NPF) Islamabad, Pakistan

Tel: +92 51- 222 8802 & 04 | Fax: +92 - 51 - 222 1937

E-mail: info@saarcenergy.org | Web Site: www.saarcenergy.org