ISSN No.: 2454- 2024 (online)

International Journal of Technical Research & Science

SMART GRID DEVELOPMENT IN INDIA WITH CHALLENGES AND OPPORTUNITIES: EXECUTION WITH GAME THEORY

Akash Talwariya[1], Santosh Kumar Sharma[2], Pushpendra Singh[3], Mohan Kolhe[4]
E-Mail Id: [1]akash.talwariya@gmail.com, [2]santoshelect@yahoo.com[3], pushpendrasingh@jklu.edu.in[4], kolhe.mohan@googlemail.com
[1]Research Scholar, JK Lakshmipat University & Assistant Professor, JECRC University, Jaipur (India)
[2]Assistant Professor, Rajasthan Technical University, India
[3]Associate Professor, JK Lakshmipat University, India
[4]Professor, University of Agder, Norway

Abstract-Advancement in energy technologies are much needed for social and economical enlargement of our society. The weakest electric grid in the world in India lost 26% of total power generation as transmission and distribution losses. The sustainable energy resources and development of efficient modules are highly required in present power system. Existing power system is designed as a one way supply system from source to utility. The objective of this paper is to study the problems of conventional power grids in India, and optimize the problems through smart grid to enhance the bidirectional flow of power in distribution network. The increasing embodiment of renewable energy sources and variable energy consumption patterns make the smart grid complex. Smart grid (SG) components such as smart meters, virtual power system and microgrid are discussed with challenges in adoption of smart grid. Renewable energy sources provides a solution against the emission of CO_2 from conventional power system by the establishment of smart grid. Game theory approach has been proposed in smart grid to conflicting the grid secure in global environment and reduces the dependency of consumers on fossil fuel sources. This paper discusses the overview of game theory, Cooperative and non-cooperative game theory.

Keywords: smart grid, climate change, microgrid, cooperative game theory, non-cooperative game theory.

1. INTRODUCTION

Power grid is the combination of electrical wires, transformers, circuit breakers, protection devices etc. Power system have mainly four operations: generation, transmission, distribution of power and control the power. The operation of existing grid is based on unidirectional power flow i.e. source to consumers. Enlargement of Distributed Generation (DG), power flow through distribution lines might reversed as it can offset some of the total feeder load, and feed power to neighboring feeders or to distribution network. Reverse energy flow creates operational hazards for equipment's which are principally designed to handle unidirectional flow of energy, like many of the over-current protection devices and line voltage regulators. Smart appliances are required in smart grid environment to control the energy flow from grid to consumer and consumer to grid. Considering the 21st century technological innovations and trends, Smart Grid is the current development of world's electric power system [1]. To obtain a flexible, clean, safe, economical, and human friendly and intelligent grid, Different organizations and countries including India have unanimously accepted SG. SG will facilitate the environment-friendly, network planning and construction, operation management, market trading and service areas, and resource saving [2-3]. Smart grid has been a common aim of power electric development of the whole world because of the increasing demand of electrical power grid, safe and steady running, as well as the requirement of high quality and reliable power supply for consumers.

2. SMART GRID IN INDIA

According to the annual report of Ministry of Power, India's transmission and distribution losses are amongst the highest in the world, averaging 26% of total electricity production, and as high as 62% in some states. These losses do not include on-technical losses like theft etc.; if such losses are included, the average losses are as high as 50%. India losses money for every unit of electricity sold, since India has one of the weakest electric grids in the world. Some of the technical flaws in the Indian power grid are: it is a poorly planned distribution network, there is overloading of the system components, there is lack of reactive power support and regulation services, there is low metering efficiency and bill collection, etc. India is venturing very fast into renewable energy (RE) resources like wind and solar. Solar has great potential in India with its average of 300 solar days per year. The government is also giving incentives for solar power generation in the form of subsidies for various solar applications; and has set a goal that solar should on tribute 7% of India's total power production by 2022. With such high targets, solar is going to play a key role in shaping the future of India's power sector. A lacuna of renewable resources is that their supply can be intermittent i.e. the supply can only be harnessed during a particular part of the day, like day time for solar energy and windy conditions for harnessing wind energy, also these conditions cannot be controlled. With such unpredictable energy sources feeding the grid, it is necessary to have a grid that is highly adaptive (in terms of supply and demand). Hence, the opportunities for building smart grids in India are immense, as a good electric supply is one of the key infrastructure requirements to support overall development [4].

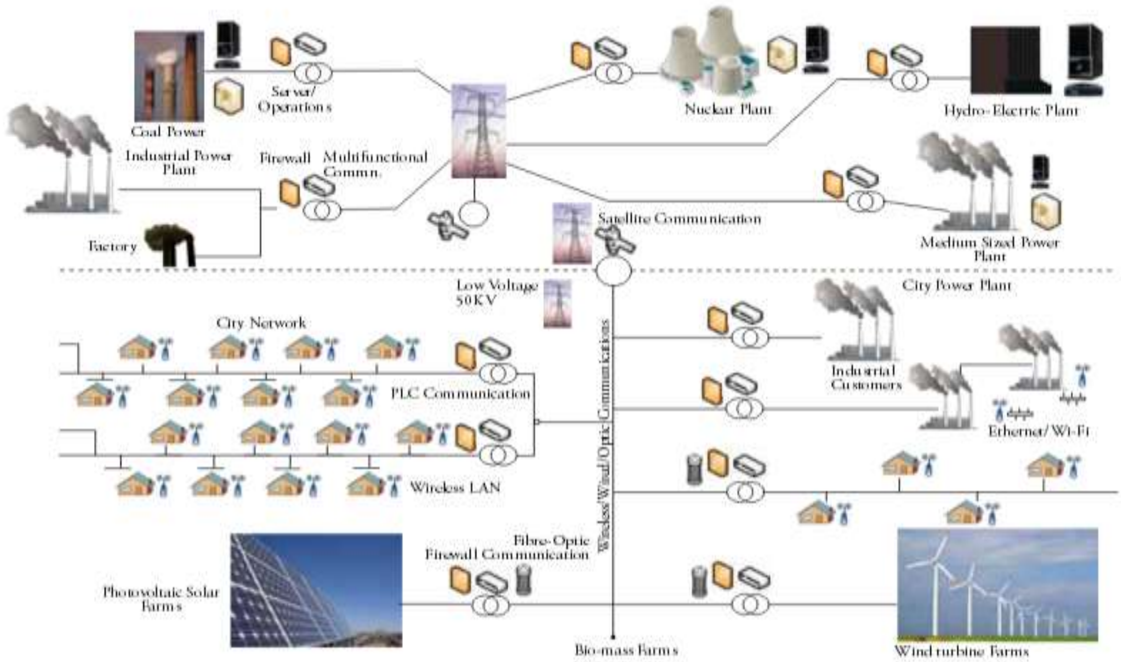

Fig. 2.1 A smart Grid - Components and Inter Linkages

3. SMART GRID TECHNOLOGIES

3.1 Smart Metering/Demand Side Management

Smart meters are microprocessor based devices that provide a two way communication capability. They help homeowners and the suppliers to manage the respective electricity usage and supply in a more efficient and cost effective manner. With the help of the information provided by such smart meters the power companies will have the capability to set up real time pricing systems for electricity.

3.2 Virtual Power Plants

The goal of virtual power plants (VPPs) (Fig 3.1) is to allow discrete energy resources (DERs) to access the energy market i.e. to feed the electricity grid constantly and reliably.

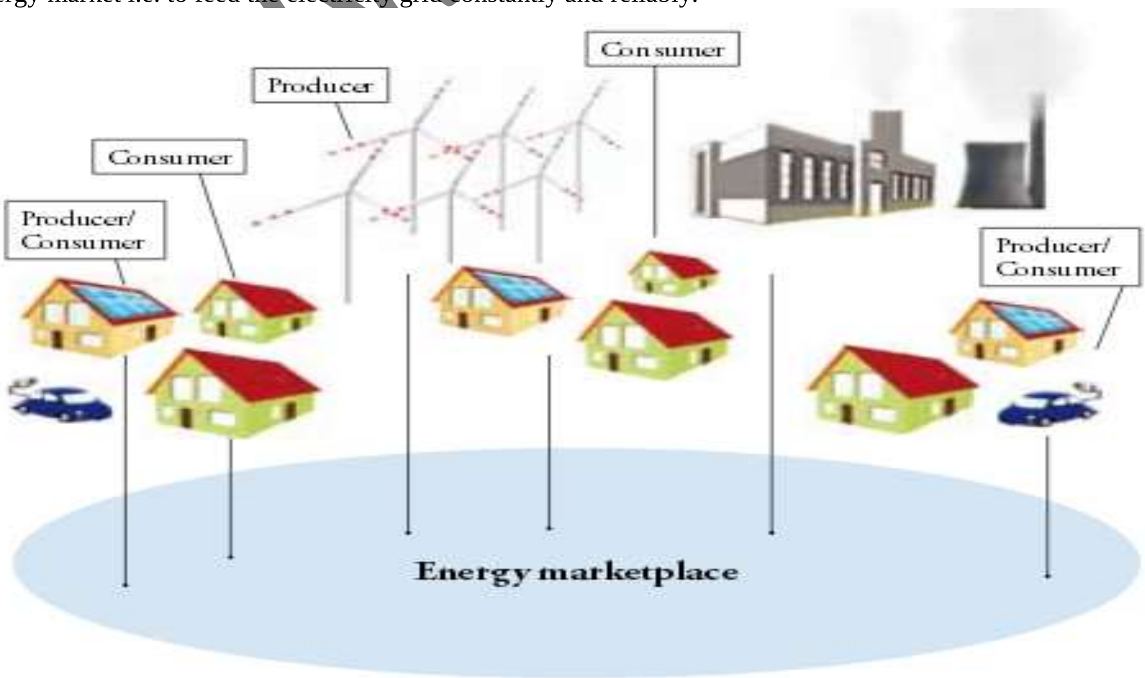

Fig. 3.1 Virtual Power Plant

DOI Number: 10.30780/IJTRS.V3.I3.2018.019

3.3 Micro Grids

A micro grid (Fig. 3.2) is a cluster of local DERs and loads in such a way that an operation is possible within the grid or in independent mode. Usually it is connected at the low voltage level but sometimes also at the medium voltage level. All these technologies can be used in India in different forms depending on the applications. Different algorithms can be used for the control of smart grids i.e. Game Theory, Genetic Algorithm etc.

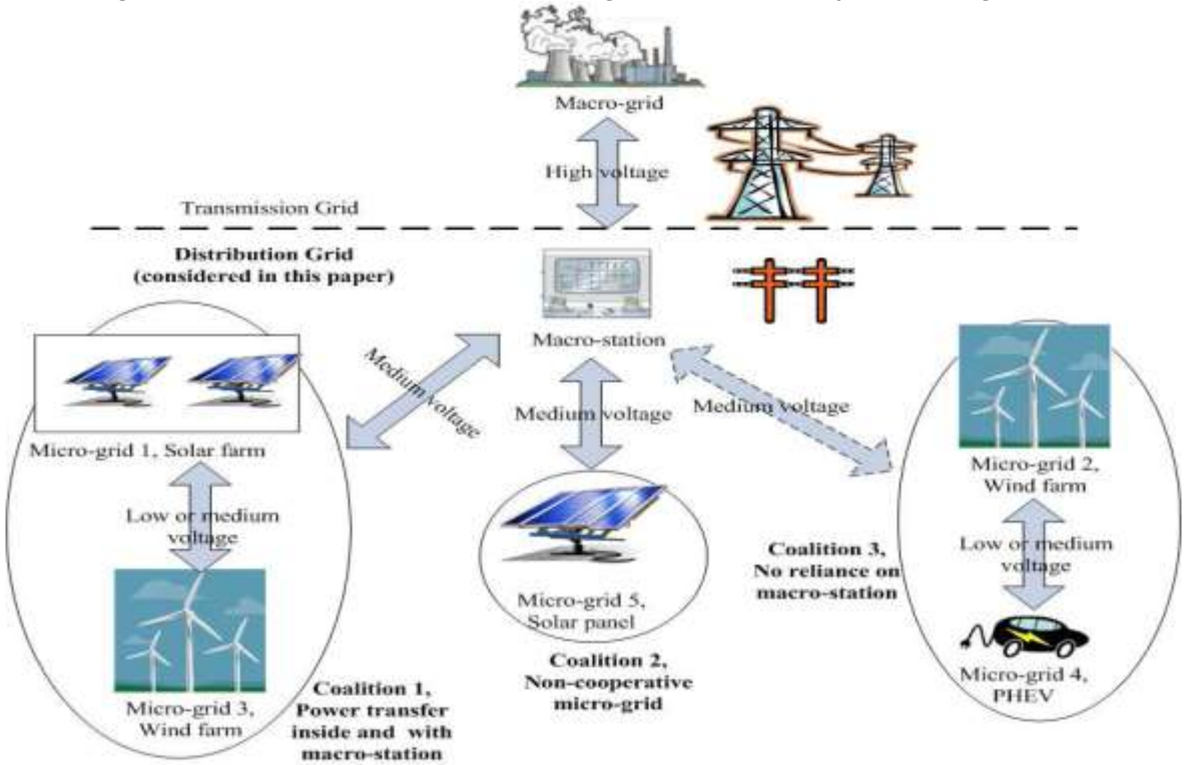

Fig. 3.2 Micro-Grid Model

4. IMPACT OF CLIMATE CHANGE ON SMART GRID

Transforming the electricity system is a crucial component of climate mitigation and adaptation [5]. Due to the high reliance on fossil fuels, electricity generation emits 26% of global greenhouse gas emissions and 41% of all carbon dioxide (CO_2) [6]. Although the Intergovernmental Panel on Climate Change (IPCC) suggests that an 80% reduction in greenhouse gas emissions by 2050 is required for stabilization of atmospheric CO_2 [7], electricity generation is projected to grow 70% by 2035 and increasing societal reliance on electricity to provide energy services related to health, food, and communication requires more resilient and robust electricity systems. Smart grid (SG) could be a crucial component of adapting the electricity system to a changing climate, as well as mitigating emissions by reducing GHG releases from the existing electric sector and by allowing electricity to assume a greater share of total energy service enhancement. Common leverage points across climate changes can be identified.

- SG investments should be assessed for potential contributions to climate change mitigation and adaptation in the short and long term. This accounting for the climate implications of electricity system investments could be a government requirement integrated into financing and regulation to guide a long term trajectory of SG roll-out that places value on both climate mitigation and adaptation. High discount rates favor near-term benefits, and additional evaluation to assess longer term impacts is warranted.
- SG initiatives that contribute to energy efficiency and electricity conservation should be a priority, as controlling demand is often the cheapest and most effective way to reduce emissions and costs. But managing demand is not just about novel technology, but also about the interactions between technology and electricity consumers, so appreciating the needs and concerns of end-users and integrating them into decisions about SG deployment is essential.
- SG initiatives that facilitate the incorporation of low-carbon generation should be encouraged. Given the climate mitigation priority of reducing fossil-fuel dependence, SG investments that contribute to displacing reliance on carbon emitting electricity generation are critically important.
- SG measures that support the emergence of local microgrids and enhance local and community-based energy systems are generally positive. Bringing generation close to the point of use reduces transmission losses, and allows the development of integrated energy solutions (multiple fuels, heat and power, and so on) in buildings, and local communities. Localization also allows for more modular and, therefore, more adaptable systems.

- Particular attention should be paid to ways in which SG can enhance system flexibility and redundancy. Climate uncertainty, and the unpredictability of future energy needs point to the importance of adaptive management approaches (that can make rapid adjustments in response to fuel price changes, resource shortages, or technical disruptions) and SG innovations can be helpful here.
- The issue of maintaining public trust and support, and here a critical factor is the appropriate distribution of costs and benefits. SG proponents need to make a clear case for the specific economic, social and environmental benefits particular investments will secure.

5. CHALLENGES AND SOLUTIONS

5.1 Policy and Regulation

No defined standards and guidelines exist for the regulation of smart grid initiatives in India. The current policy and regulatory frameworks were typically designed to deal with the existing networks and utilities. With the move towards smart grids, the prevailing policy and regulatory frameworks must evolve in order to encourage incentives for investment. The new framework will need to match the interests of the consumers with the interests of the utilities and suppliers to ensure that the societal goals are achieved at the lowest cost to the consumers.

5.2 Cost

If smart grids had made easy business sense, they would have been the norm everywhere. Cost is clearly one of the biggest hurdles in implementing smart grids. Some older equipment that cannot be retrofitted to be compatible with smart grid technologies will have to be replaced. This may present a problem for utilities and regulators since keeping equipment beyond its depreciated life minimises the capital cost to consumers. The early retirement of equipment may be an issue. Cost of implementing smart grids runs in crores of rupees. The benefits from smart grids are not just meter readings but include reduction in equipment failure, better quality of supply and greater use of green energy. It takes careful societal cost-benefit analysis, beyond return of investment calculations, to justify the use of a smart grid.

5.3 Lack of Awareness

The level of understanding of consumers about how power is delivered to their homes is often low. So, before going forward and implementing smart grid concepts, the consumers should be made aware of what a smart grid is, how it can contribute to a low carbon economy and what benefits they as users can drive from smart grids. Therefore, consumers must also be made aware of their energy consumption pattern at home, offices, etc.; policy makers and regulators must be very clear about the future prospects of smart grids; and the utilities need to focus on the overall capabilities of smart grids rather than mere implementation of smart meters.

6. CYBER SECURITY AND DATA PRIVACY

With the transition from analogous to digital electricity infrastructure comes the challenge of communication security and data management. Since digital networks are more prone to malicious attacks from software hackers, security becomes a key issue. In addition to this, concerns on invasion of privacy and security of personal consumption data arise. The data collected from the consumption information could provide a significant insight into a consumer's behavior and preferences. This valuable information could be abused, if correct protocols and security measures are not adhered to. These issues should be addressed in a transparent manner, to minimize any negative impact on a customer's perception. The systems should be designed with security as a priority and should be well protected against software hacking and other such malicious activities.

7. GAME THEORY IN SMART GRID

The micro-grid operations will be based on following theories:

7.1 Non-Cooperative Game Theory

Non-cooperative game theory allowed the players to optimize without any coordination or communication in the actions of invalid functions, used to analyze the strategic decision processes of a number of independent entries. It can be categorized into two categories one is static and second is dynamic games. In static games players can takes action only ones but in dynamic games players have information about others and take action more than once [8].

7.2 Cooperative Game

Players are allowed to communicate directly to another's are known as cooperative games. i.e. in politics many parties may decide to merge into a cooperative group to increase their chances some players agree the terms under the cooperate it is called Nash Bargaining games but if whole party is ready for coalesce it is called coalitional game. Cooperative game theories provide tools which allowed the players to decide the terms in which they cooperate in both of its theories [9].

8. MICROGRIDS USING NONCOOPERATIVE GAME THEORY APPROACH

Microgrid has objectives and constraints for each and every component of power system. Many technologies are dealing with the energy management but smart grid has evolved itself as an ultimate solution of system overloading. Non-cooperative game theory desired to equilibrium in which load and source both are able to control their power and optimize the utilities. Various other authors discuss several other cases of equilibrium and efficiency improvement [10-11]. Towards that goal, the non-cooperative game approach is used for controlling the load and source side power management.

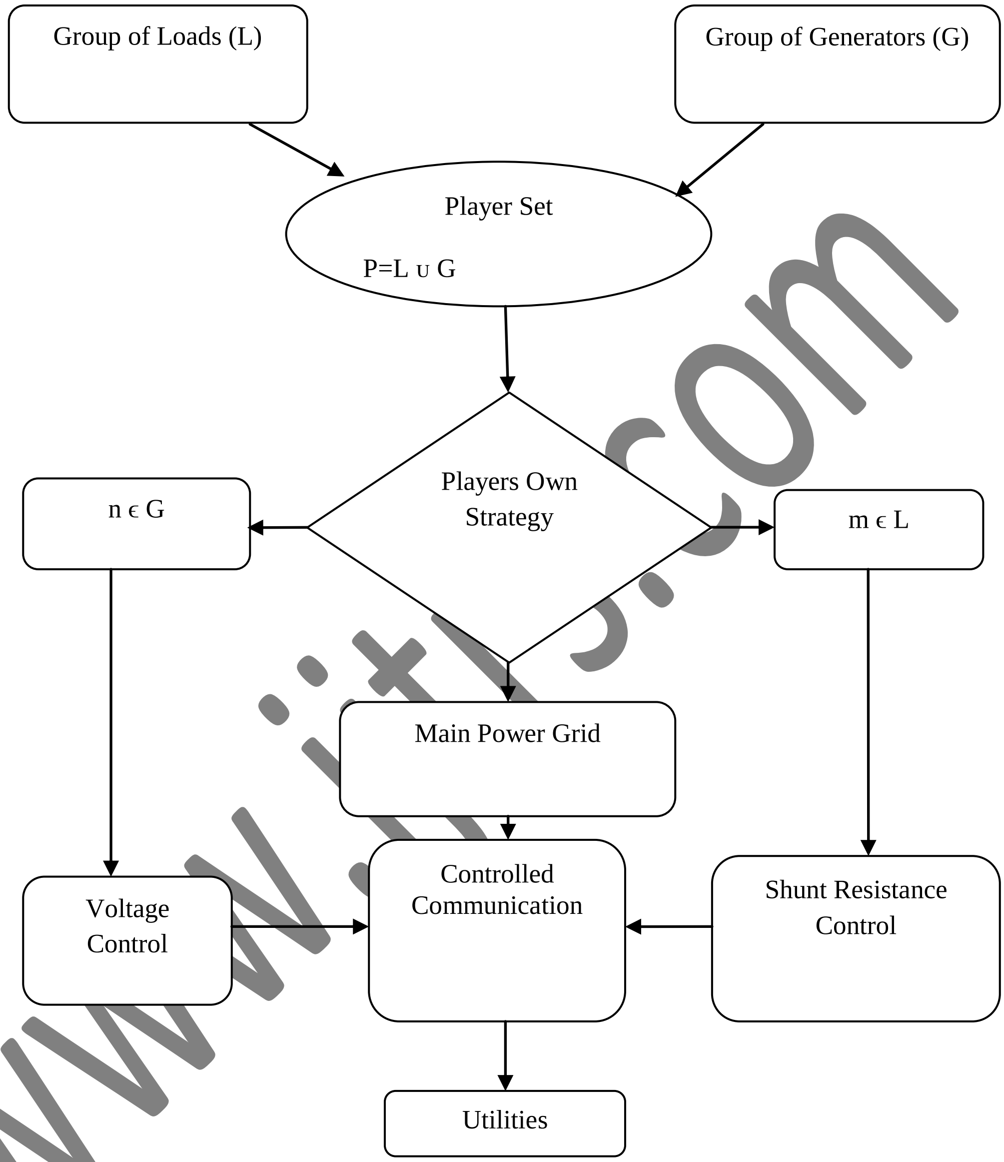

Fig. 8.1 Non-Cooperative Game Theory

The functions of non-cooperative game theory are as follows

- Non-cooperative game theory controls both source and load side management in small systems.
- Non-cooperative games have a player set (P) which include group of different kind of loads (L) and distributed generators (G).
- According to game theory concept each player has his own strategy.
- If source node n ϵ G; the strategy is to regulate the voltage.
- If Load node m ϵ L; the strategy is to control the variable shunt resistance of the ground.

9. MICROGRIDS USING COOPERATIVE GAME THEORY APPROACH

Cooperative game theory approach deals with this interconnection of small size grids have several advantages-

- Reduce the wastage of power in transmission, exchange power between nearby microgrids.
- Reduce the reliance on main grid.
- Reduce the requirement of system on Non-conventional energy sources.

- Reduce the pollution which is generated from non-renewable sources.
- Reduce the need of storage.

Consider a distributed substation which is connected to N numbers of microgrids interconnect all the systems with power grid. This system operation has been shown in fig. 9.1.

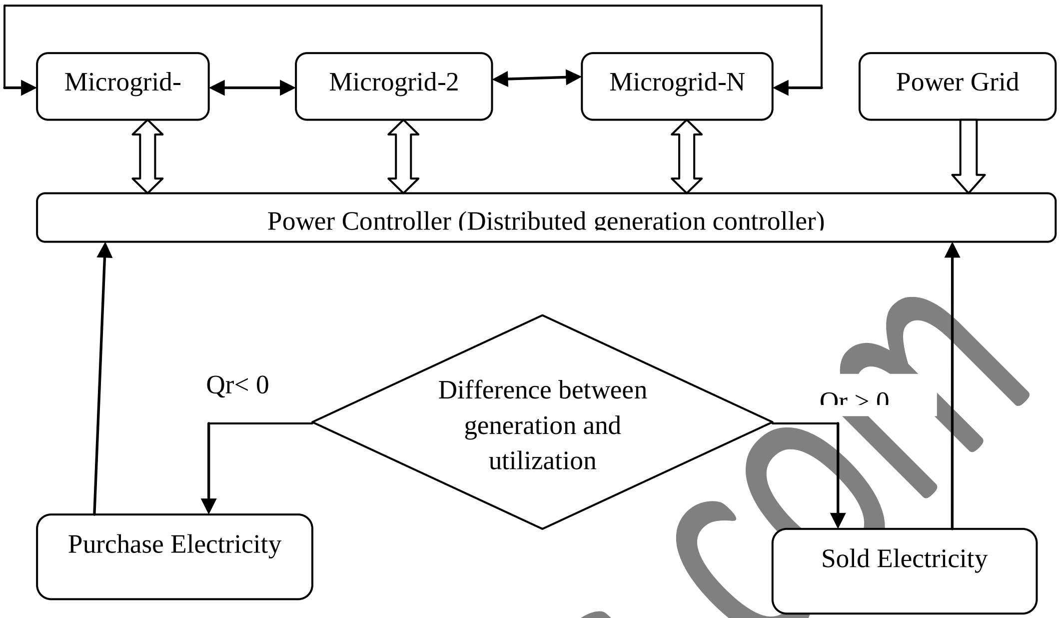

Fig. 9.1 Cooperative Game Theory

- Each grid r ϵ N, provides services to consumers and the difference between consumption and generation through distributed generators which is defined by $Q_{r.}$
- Due to random behavior of certain consumers on a microgrid, Qr is varied.
- If Qr is greater than zero power generation is higher as compared to consumption sell the power to other microgrids.
- If Qr is less than zero power generation is less then consumption, microgrid need to purchase power from others.

Cooperative game theory does not require any storage, therefore all microgrid exchange some amount of power Q_r with main smart grid or power grid [13-14].

CONCLUSION

Power system with large transmission and distribution losses need the solution and smart grid provides with its two way power transmission ability, It is difficult to analyses the performance and benefits of smart grids without implementation in practical system. The paper discussed the issues of conventional grid and the impact of climate change due to CO_2 emission. It should be emphasized that any plan must be adaptable to the unique needs, cultural and political realities, and resource constraints of different regions, states and localities. In this paper, two approaches of game theory first is Non-cooperative game theory which deals with individual consumer and second is cooperative game theory which deals with interconnected microgrids has been studied. This paper gives a comparative study of both these methodologies of game theory. Both the game theories may be applied simultaneously on system. Non-cooperative for single mircogrid and cooperative game theory for interconnected microgrids.

REFERENCES

[1] S. Massoud Amin and B.F. Wollenberg, "Toward a smart grid: power delivery for the 21st century," IEEE Power and Energy Magazine, Vol. 3, No. 5 Sept.-Oct. 2005, pp. 34-41.

[2] Pushpendra Singh, D.P. Kothari & Mool Singh, “Integration / Analysis of Green Energy and Conventional Electricity Generation with Interconnected Distribution Networks” vol.-5. N.-5, pp.2299-2306, Part (B), October-2012, International Review on Modelling and Simulations (IREMOS) Impact Factor 6.55.

[3] Pushpendra Singh, D.P. Kothari & Mool Singh, “Voltage control in Distribution Networks Having DGs by using UPFC” vol.02, issue no.1, pp. 31-38, ,April 2010 – June 2010, International Journal on Electronic & Electrical Engineering Systems (IJEEES).

[4] Sharma, D., Talwariya, A., Pandey, A., & Singh, P. (2017, April). Shrouded problems of solar power plant and recommendations. In Power and Advanced Computing Technologies (i-PACT), 2017 Innovations in (pp. 1-5). IEEE.

[5] Kasperson, R.E.; Ram, B. Rapid Transformation of the US Electric Power System: Prospects and Impediments. In Toward Successful Adaptation: Linking Science and Practice in Managing Climate Change Impacts; Moser, S.Boykoff, M.Eds.; Routledge: Oxon, UK,2013.

[6] International Energy Agency. CO2 Emissions from Fossil Fuel Combustion; IEA: Paris, France, 2012. Available online: http://www.iea.org/co2highlights/co2highlights.pdf (accessed on 28 August 2013).

[7] Intergovernmental Panel on Climate Change. The Mitigation of Climate Change, Working Group III Report; Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A., Eds.;Cambridge University Press: Cambridge, UK, 2007.

[8] T. Bas¸ar and G. J. Olsder, Dynamic Noncooperative Game Theory. Philadelphia, PA, USA: SIAM Series in Classics in Applied Mathematics, Jan. 1999.

[9] E. Karangelos and F. Bouffard, “A cooperative game theory approach to wind power generation imbalance cost allocation,” in Proc. Workshop on Power Systems Computation Conference, Stockholm, Sweden, Aug. 2011.

[10] K. E. Holbert, G. T. Heydt and H. Ni, “Use of satellite technologies for power system measurements, command and control”, In Proceeding of IEEE, Vol. 93, issue 5, May 2005

[11] T. Jin and M. Mechehoul, ``Ordering electricity via internet and its potentials for smart grid systems," IEEE Trans. Smart Grid, vol. 1, no. 3, pp. 302_310, Dec. 2010.

[12] W. W. Weaver and P. T. Krein, “Game-theoretic control of small-scale power systems,” IEEE Trans. on Power Delivery, vol. 24, no. 3, pp.1560–1567, Jul. 2009.

[13] F. A. Mohamed and H. N. Koivo, “Multiobjective optimization using modified game theory for online management of microgrid,” European Transactions on Electrical Power, vol. 21, no. 1, pp. 839–854, Jan. 2011.

[14] Talwariya, A., Sharma, D., Pandey, A. K., & Singh, P. (2016, December). An execution of smart grid with game theory. In Recent Advances and Innovations in Engineering (ICRAIE), 2016 International Conference on (pp. 1-4). IEEE.