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Review: Design, Simulation and Economic Analysis for Decentralized and Distributed Power Generation in India

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ABSTRACT: The term "Decentralization" means shifting the focus from centralized structure to many decentralized structures – transfer of responsibility. It embraces a variety of concepts which must be carefully studied and analyzed in determining the appropriate technology or their mix for specific requirements. In this paper we have studied the present status and practices of Decentralized and Distributed power management systems. It is observed that most of the studied decentralized projects are installed and running with state support and they are not economically sustainable on their own. This is the biggest barrier in mass replicability of such technology. Our research aims to develop a duly simulated sustainable model for Decentralized and Distributed Power management and possible pathways for its deployment, based on local resource assessment and energy demand.

I. INTRODUCTION

There is an imperative need of developing new strategies and models for meeting the swelling demand of electricity in developing nations like India. One of the promising models for this would be Decentralized Distributed Power Generation. Currently, the Indian power system faces numerous challenges like ageing grid infrastructure, growth in demand, supply security, emission reduction and integration of renewable energy sources, electrical vehicles, and rural electrification. According to the Indian Census 2011, 75 × 106 households in India [5(1)] still do not have access to electricity, the reason being low levels of access to modern energy and not low demand. India's per capita energy consumption is only 1075 kWh in 2015-16 (as per World Energy Outlook) which is one-third of the global average compared to other developing nations despite of having abundant renewable energy resources. Decentralized Distributed Power Generation offers methods not just to meet these challenges but also to develop efficient, sustainable, affordable, and cleaner energy to the people [5].

India is the second largest market in the world for new electricity capacity. Its total electricity consumption is expected to increase by 223% from base line consumption in 1995 to 2020. In comparison, electricity consumption during the same period in the Organization for Economic Cooperation and Development (OECD) countries is expected to increase by only 58% [1]. Currently, most of India's electricity consumers are in metropolitan areas; however, approximately 60% of the population lives in rural areas. This sector has benefited from the government's rural electrification programs, but most villages still face recurrent power shortages, and some have no access to power. As a result, there is a substantial potential market for supplying reliable power to rural consumers. Economies of scale provide a greater than proportionate return for a proportionate change in all inputs; if inputs in an industrial process are doubled, outputs are more than doubled. As more products is made or service becomes available, the per-unit cost decreases. Conversely, inputs and outputs in a situation with constant returns to scale have a one-to-one relationship. Scale economies are attributed to industrial processes, infrastructure services such as power and water, and regional economic development. Industrial and economic development is positively correlated with the rise of cities. In explaining rates of urbanization, regional economists state that economic activities agglomerate at certain locations, mainly because of the benefits of economies of scale. Urbanization draws the major economic players to a concentrated area. India is no exception to this trend. Its rapid urbanization justified building large-scale power plants close to cities to efficiently serve their growing customer bases. With a large-scale plant, more electricity consumers can be served from a central source. Multiplier effects also increase as the size of the establishment increases. As economies agglomerate, labor moves into the area to take advantage of more jobs. The number of ancillary businesses then rises as the number of potential customers' increases [3].

In India till 2010, the MW scale solar plant was a dream, as the capital cost of 1MW solar PV plant was in tune of Rs.15 Crores, roughly 3 time the coal based power plant and the situation of cost per unit of energy was even worsen i.e. Rs.15 per unit. But due to fast scale up activities in solar PV sector, today 1MW SPV capex is about Rs.5.00 Crores and per unit generation cost is comparable to conventional energy i.e. Rs.4.34 without any emissions.

II. LITERATURE REVIEW

Based on recent research [HEC Paris (7)], we have identified different categories of barriers: [6]

-**Technical Issues:** distribution networks will have to be reinforced and partly redesigned to cope with new capacities.

Besides, they will have to incorporate both control and protection software and hardware to coordinate the distributed generators and make.

- **Price Competitiveness**: for such a move toward distributed generation to be efficient in terms of both performance and price, distributed generation will have to be used where it is more competitive than centralized generators i.e. at congested areas where it is uneconomical to build a centralized plant or as cogeneration facilities. This will also mean more research and development for new technologies such as fuel cells in order to reduce the cost per kWh.

- **Regulatory Barriers:** significant work has to be undertaken to alter the regulatory environment the distributed generators are facing: regulatory hurdles still impede the spread of distributed generation as distribution network operators have little incentive to give them access to the distribution network while distributed generators are unable to cash in the positive impact they have.

- **Environmental Impact:** distributed generation does not necessarily mean clean generation. Indeed, diesel reciprocating engines often used as back-up distributed generators tend to be the worst performers in terms of greenhouse gas emissions. Distributed generation, to be a sustainable alternative paradigm, will thus have to rely on the cleanest technologies or favour efficient uses maximizing energy efficiency and reducing emissions such as cogeneration [7].

Thus, Decentralized Distributed Power Generation is any small-scale power generation technology that provides electric power at a site closer to customers than central station generation. A distributed power unit can be connected directly to the consumer or to a utility's transmission or distribution system [4,2].

The Rise of Distributed Power By Brandon Owens (General Electric Company, 2014)

By 2020 distributed power will play an even larger role. GE estimates that annual distributed power capacity additions will grow from 142 GW in 2012 to 200 GW in 2020. That's a 58 GW increase and represents an average annual growth rate of 4.4 percent. During this period, investment in distributed power technologies will rise from $150 billion to $206 billion. As a point of reference, during this same period, global electricity consumption will rise from 20.8 to 26.9 terrawatt-hours (TWh). This represents an average annual growth rate of 3.3 percent. Thus, through the end of the decade, distributed power capacity additions will grow at a rate that is nearly 40 percent faster that global power demand (11).

A Euro electric Report, June 2012

Europe's electricity system is undergoing profound changes. The EU is planning a de-carbonization path that will see the EU and other industrialized countries reduce their emissions by up to 95% by 2050. To reach this ambition of a carbon-neutral power supply, the electricity sector will see an increase of variable renewable energy sources (RES) like wind and solar power in the energy generation portfolio. As a consequence, the electricity system will not only continue to face varying electricity demand throughout the day, but increasingly experience generation-driven fluctuations. This will lead to challenges in ensuring the stability of electricity supply. Electricity storage is one of the flexible solutions to reduce temporary mismatches between supply and demand. Conventional and pumped hydropower already support the integration of increasing amounts of RES by providing the necessary flexibility and storage capacity to balance fluctuations. However, peak production of intermittent renewable sources that feed into the medium and low voltage grid will require additional small-scale, grid-connected electricity storage solutions. This 'decentralised' storage can support the development of distributed generation. It can also provide a range of applications and services to the distribution system operators (DSOs) facing challenges such as increasing peak loads and stricter power quality requirements (12).

Enrique Kremers and Pablo Viejo, European Institute for Energy Research - EIFER (2010)

An agent based model for simulation of micro-grids has been implemented using Any Logic. The model offers a clear two layer structure, which allows representing both physical and logical interactions between the elements. The logical layer offers a robust base to implement agent communication in real time. The physical layer provides the technical results of the power flow calculation integrated in the model. This allows to compute real time simulations of the grid, which can provide valuable information before having implemented the real grid.

The model is mainly intended to design and test micro-grids and it can be used as a tool for design, development and demonstration of control strategies specially Centralized Supervisor Control and Decentralized Load-Dispatch Control, design and demonstration of micro-grid operation strategies, design and trying of micro-grid communication buses, micro-grid optimal design, and economic benefits demonstration.

Policy Implications of Decentralization: James Newcomb, Virginia Lacy, Lena Hansen, and Mathias Bell with Rocky Mountain Institute (2013)

With smart thermostats, efficient refrigerators, and solar panels all available at the local hardware store, the role of distributed energy resources is growing. Distributed energy resources can deliver clean electricity on site, reduce electricity demand and provide much-needed grid flexibility. Ensuring that policies and markets adequately support distributed resources to keep costs low, enhance reliability, and support clean energy integration (14).

Distributed and decentralized control of the power grid, By Angel a. Aquino-lugo (2010)

Four decentralized optimization techniques are studied in two different distribution networks. From the analysis, the Lagrangian relaxation algorithms show the best results to implement a decentralized scheme to control reactive resources. Since capacitors are another reactive power resource to be controlled, the dissertation also presents a decentralized optimization algorithm to minimize losses in the distribution network. The decentralized algorithm results are found to be similar to those using a centralized algorithm.

An algorithm is introduced to find a local solution to reactive resource problems in the distribution network. The algorithm is based on sensitivities of voltages to reactive resources to estimate the top of a feeder bus voltage of a particular region inside the distribution network. The algorithm is shown to effectively find a solution to a local problem, and the results are similar to a centralized optimization problem.

The framework and the algorithms presented in this dissertation integrate agent-based technologies to manage the data and control actions required to operate this type of architecture (15).

Distributed energy generation and sustainable development, Kari Alanne, Arto Saari. Laboratory of Construction Economics and Management, (2004)

The concept of a 'distributed energy system' refers to an energy system in which energy on version units are located close to energy consumers In addition to the distribution of technology, a distributed energy system means the reallocation of decision-making, expertise, ownership, and responsibility in terms of energy supply. In practice, the energy system in the future is going to be a mixture of centralized and distributed sub-systems, operating parallel to each other. In this context, if an existing energy system already includes many decentralized sub-systems in a certain region, the region is likely to be favorable for the further development of distributed energy generation. If the most favorable regions can be recognized in this respect, energy utilities and product suppliers will become aware of the best market opportunities for distributed energy technology. In this article, we use the degree of decentralization as a means to evaluate regional energy systems. This analysis can also be applied when evaluating the vulnerability of an energy system.

The main characteristics of a sustainable energy system are (cost-) efficiency, reliability, and environmental-friendliness. Local resources and networks are utilized effectively and the introduction of new techno economic and political solutions is also actively promoted. The ability of distributed systems to rise to the challenge of sustainable development is mainly based on flexibility, locality, and networking. The flexibility of distributed energy systems is associated with their scalability and ability to utilize various energy conversion technologies and fuels. An improvement can be seen also in the reliability of energy supply because of the tendency of distributed systems not to 'put all the eggs in one basket'. This is related to their ability to operate in networks and utilize local resources. In addition, distributed energy systems are environmental-friendly because of the absence of large power plants and transmission lines. When it comes to local decision-making and expertise, the 'educative' effect of distributed energy generation should not be underestimated. The drawbacks of distributed energy generation can be seen as the 'other side of the coin'. They are mainly associated with the fact that distributed systems are 'fragmented'. There are problems to be solved, linked to the questions of responsibility, the compatibility of single units, and also the lack of common standards and laws (16).

Decentralization of Governance and Development, Pranab Bardhan, University of California (2010)

It is quite plausible to argue that in the matter of service deliveries as well as in local business development control rights in governance structures should be assigned to people who have the requisite information and incentives, and at the same time will bear responsibility for the (political and economic) consequences of their decisions. In many situations this calls for more devolution of power to local authorities and communities.

But at the same time it is important to keep in mind that structures of local accountability are not in place in many developing countries, and local governments are often at the mercy of local power elites, who may frustrate the goal of achieving public delivery to the general populace of social services, infrastructural facilities and conditions conducive to local business development. This means that decentralization to be really effective has to be accompanied by serious attempts to change the existing structures of power within communities and to improve the opportunities for participation and voice, and engaging the hitherto disadvantaged or disenfranchised in the political process. After all, the logic behind decentralization is not just about weakening the central authority, nor about preferring local elites to central authority, but it is fundamentally about making governance at the local level more responsive to the felt needs of the large majority of the population. To facilitate this the state, far from retreating into the minimalist role of classical liberalism, may sometimes have to play an activist role in enabling (if only as a 'catalyst') mobilization of people in local participatory development, in neutralizing the power of local oligarchs, in providing supra-local support in the form of pump-priming local finance, supplying technical and professional services toward building local capacity, acting as a watchdog for service quality standards, evaluation and auditing, investing in larger infrastructure and providing some coordination in the face of externalities across localities (17).

The Australian Decentralized Energy Roadmap: An intelligent grid research cluster report institute for sustainable futures, university of technology, Sydney (2011)

Australia currently faces steeply rising energy bills, and it often seems that whatever is proposed to reduce carbon emissions would increase energy costs even further. Conversely, many measures proposed to reduce energy costs pressures would raise emissions. Consequently, proposals to address either issue are contentious and are often blocked and community frustration at this deadlock grows. However, Decentralized Energy (DE) offers a potential solution to this dilemma. Decentralized Energy refers to energy technologies and practices that optimize the use of local resources and reduce the need for large-scale energy supply infrastructure. The three elements of DE are: efficient use of energy, peak load management and Distributed Generation. Each of these elements offers significant potential benefits in its own right, but when combined, Decentralized Energy has the potential to offer major cost savings and carbon emission reductions while reliably meeting customer energy needs (18).

Distributed Energy: A Discussion Paper of Energy Aware Communities (February, 2012)

Distributed Energy is decentralized electricity, generated at or near the place where it is used. It can be used to help reduce greenhouse gas emissions from electricity use. Often it is produced from renewable resources, such as wind, solar, or geothermal. Another common source is waste heat from commercial or industrial uses, which can be used to power engines or turbines to generate electricity (19).

A Secure Decentralized Data-centric Information Infrastructure for Smart Grid, Young-Jin Kim, Marina Thottan IEEE Communication Magazine (2010)

In this article, the author demonstrate the benefits of decentralized and data-centric information infrastructure for the next generation power grid. We propose a secure middleware architecture that leverages these features and can support the operation of the power grid reliably, efficiently, and scalably by eliminating bottleneck failure points. The information infrastructure presented here differs from a typical distributed system due to traits that are characteristics of the power grid applications such as the coexistence of both of LAN and WAN system, strict requirements of both latency and reliability and a combination of both data and event transactions. As an additional contribution, we discuss our choices and implementation details; we also take note of the important challenges that we will face as we plan the development and deployment of the next generation grid (20).

Other related literatures

India has nearly 600,000 villages and has a large potential for Decentralized Energy (DE) systems (Ravindranath and Hall, 1995). Officially, over 500,000 of India's 600,000 villages are "deemed" to be "electrified": defined as a minimum of 10% of households being connected to power supply (Reddy, 1999). Only 44% of India's 138 million rural households use electricity for lighting — a particularly efficient and desirable application of power, the remaining 55% still use kerosene — a grossly inefficient source, which is increasingly becoming expensive too (Ravindranath et al., 2004). This also affects rural industries, with negative impact on employment generation and income (Reddy and Subramanian, 1980; Burrough, 1986; Ravindranath *et al.,* 2000). During the past last quarter of the century, a significant thrust has been given to the development, trial and induction of a variety of RE technologies for use in different sectors (Goldemberg and Johansson, 1995; Ravindranath *et al.,* 1994). [8]

In India the electricity sector has always confine to centralized electricity planning with large component of thermal power generation from fossil fuels and mainly dominated by coal. However, the evidences shown that this centralized planning has not been able to keep the balance between demand and supply at the moment (Banerjee, 2006). This centralized electricity generation has resulted in inequities, external debate, and environmental degradation, which can be seen from the fact that still near by 70% of Indian population live in rural areas and around 40% of total population live without any modern energy services (Kaundinya, Balachandra, & Ravindranath, 2009). This situation mainly arrived from the adoption of centralized energy planning, it snubbed electricity demand of rural poor community (R.B. Hiremath 2009). Centralized electricity generation with coal fired power plants all over the world has been the main culprit and major cause of climate change (Bell, 2007). In the 11th five year plan of the government of India, the expansion of coal power generation to produce around 79 GW of electricity is expected. However, this would not be good news from the climate change point of view. If the government of India wants to meet the target of providing electricity to all by 2012, the government should think very seriously to provide electricity first to the remote areas, where the grid connectivity is not feasible. This can be done by deploying the large scale renewable energy (RE) options from the supply side and efficient energy management from the demand side. The efforts need to be in place from both sides (Reid, Simms, & Johnson, 2007). [10(3)]

Case studies: biomass power

West Bengal: Gosaba Island rural electrification. About three million people inhabit the Delta Region of Sunderbans, West Bengal State. Two million of them do not have access to electricity. A 500 kW gasifier was installed in Gosaba Island off the Sundarbans, West Bengal, for electrification of five villages comprising more than 10,000 people. Gosaba Island is located south of 24-Parganas district at a distance of 115 km from Kolkata. After an initial survey of the area, the West Bengal Renewable Energy Development Agency (WBREDA) decided to set up a 500 kW gasifier-based power plant along with an energy plantation (to meet fuel wood needs without affecting agricultural lands) in 100 ha of wasteland and a rural energy cooperative for regular operation of the power plant. The 500 kW (5×100 kW) biomass gasifier dual fuel power generation system (70% biomass+30% diesel)was installed in June,1997. The system had only 16 customers when the operation started because people did not believe that it really works. The island developed dramatically since the installation of power station with many commercial establishments (shops, hotels, etc.) attracting even people from nearby islands for shopping. The project is 100% funded by the government since this is a pilot project but owned and operated by Gosaba Rural Energy Cooperative. The cooperative organizes 75 ha of energy plantation. Biomass fuel is supplied by both the farmers and the plantation.

Tamil Nadu: Gasifier installations at Odanthurai Panchayat. Ankur Scientific, which is a leading gasifier manufacturer (67% share of total gasifier installations), installed 60 gasifier systems in Tamil Nadu State in one year during 2004. Of the 60 systems, 57 were of 9 kWcapacity. In one such case, Odanthurai Panchayat (Panchayat is a general term of village cooperatives in India) installed a 9 kW biomass gasifier power generation system to substitute the grid electricity usage for pumping drinking water supply. The biomass gasifier system saves about 70% of pumping cost compared to using grid electricity . This Panchayat also has other renewable energy projects such as solar street lighting and biogas production using human and domestic animal waste. The biogas system is connected to each house for cooking purpose. This has resulted in people hardly using firewood. Panchayat purchases wastewood from a saw mill in the village at very low price of Rs. 0.3/kg (US$6.7/t) as fuel for the gasifier. The low price is mainly the result of low demand for wood in the village. Though, the grid electricity tariff of Rs. 4.5/kWh (US$0.10) is considered inexpensive, it is not preferred because gasifier installation saves large amount of cost of the water supply system.

Karnataka: Hosahalli and Hanumanthanagara villages. This case presents the experiment of the Centre for Sustainable Technologies (CST), Indian Institute of Science, Bangalore, India to demonstrate and disseminate biomass-based electricity generation systems in non-electrified villages. Hosahalli and Hanumanthanagara are located in the semi-arid Tumkur district of Karnataka State. The population, of 220 and 300 respectively, is dominated by the farming community of whom over 80% have agricultural lands. The main source of drinking water was a bore well and the collection of water involved enormous drudgery. There was no assured irrigation water supply. Main supply was from a small irrigation pond, which was dependent on the rainfall. A 20 kW capacity biomass gasifier (see Table 3) developed by CST has been installed in each village. These gasifiers have an efficiency of around 23% and are connected to a diesel engine to run on dual fuel (coupled to a generator). A diesel replacement of 85 to 90%was achieved in field conditions. Woody biomass is obtained from social forestry plantation grown for meeting village biomass needs. Its specific fuel consumption per unit of electricity generation is around 1.25 kg/kWh.

The investment cost for the 20 kW biomass gasifier power generation units was Rs. 850,000 while the investment cost for services such as irrigation, drinking water, flour mill, and electrical wiring of all homes was Rs. 650,000. The total investment cost for power generation and provision of services was about Rs. 1,500,000 for each village. The operation and maintenance cost was about Rs. 3.34/kWh at a full load of nearly 20 kW (Ravindranath et al., 2004). Electricity was provided for home-lighting, street lighting, pumping drinking and irrigation water, and operation of a flour mill. These services were provided during fixed hours agreed to by the village community. Electricity was generated and provided for over 90% of the days. The main responsibility for managing the system was with the Village Management Committee. The functions are: supervision of the operation of the system, protection of the forest and equipment, insurance of the payment for the services, ensure compliance to agreement reached, day-to-day decision-making, monitoring of income and expenditure. Local trained operators were responsible for operation and maintenance, collection of charges, wood supply and recording basic data on performance. CST provided technology support, organized major repair and replacement and undertook monitoring of the system. Village community received the benefits of quality lighting, safe drinking water supply, flour milling and irrigation water supply and sharing arrangements.

Impacts and lessons learnt

Benefits of biomass-based distributed generation (DG) systems accrue by changing from a remote, centralized service that uses imported and indigenous fuels, to building a localized system based on modular technology that uses indigenous fuels. Decentralized power that uses biomass can avoid T&D losses, include a participatory project development process, and increase rural employment based on an indigenous resource. The modularity associated with DG systems offers consumers a number of benefits such as: (a) a degree of energy independence, (b) opportunities for local control to improve security of supply, (c) equal or better power quality, and (d) a cleaner environment. The decentralized power generation systems based on biomass, implemented in India, have shown the technical and operational feasibility as well as acceptance by the local communities. However, economic viability of biomass-power systems is yet to be demonstrated in India.

III. CASE STUDIES: SOLAR POWER PLANTS

West Bengal: Sundarban region. Providing power and drinking water facility to the large population in the isolated islands of the Sundarban region in West Bengal had been a perpetual problem in the past, as it was not practically possible to link the islands with the mainland power grid. The Ministry of New and Renewable Energy (MNRE), through the West Bengal Renewable Energy Development Agency (WBREDA), came forward, way back in 1996 to solve this problem in two major islands of the Sundarban region i.e., Sagar Island and Moushuni Island. Sagar Island is a large island with an area of around 300 sq km spread over 43 villages and a population of over 160,000, situated 110 km south of Kolkata. The main hardship of the people had been non-availability of electricity. Till 1996, only a few diesel generating sets of aggregate capacity of 300 kW were in service to provide electricity to some selected 400 consumers for a few hours in the evening. The operation and maintenance requirements of these generators were quite high and at the same time causing adverse environmental pollution. The year 1996 changed the situation for the better when MNRE identified Sundarban Region as one of the high focus areas under its SPV programme and started providing necessary funds to WBREDA for setting up of SPV power plants there. The first 26 kWp SPV plant was commissioned in Kamalpur village in Sagar Island with only 19 consumers in February, 1996. Subsequently many such power plants with aggregate SPV capacity of 300 kWp are operational in Sagar Island serving around 2000 families. Today, hospital services, water supply, etc. are being served through solar energy to some extent. The solar generated electricity constitutes more than 50% of the total electricity consumed in Sagar Island. Moushuni, another large island in Sundarban region, has earned the distinction of having India's largest stand-alone SPV power plant with installed capacity of 55 kWp, commissioned in April, 2001. It is located at Bagdanga village under Namkhana block in south 24 Parganas district. Already about 250 different categories of consumers are being served with the three phase, grid-quality power from this power plant. This benefit will be extended further to another 200 families in near future, for which new distribution lines are being laid. Power is being supplied through 5 km overhead distribution system network for duration of 6 h in the evening.

Orissa: Salepada Power Plant. Salepada is a small hamlet of the Gatibeda revenue village in Sunabeda Gram Panchayat of Komna block in the state of Orissa. A total of 40 households are located in the village, with a total population of 206 inhabitants. Salepada possesses sufficient shadow free open space and receives adequate solar insolation for about 300 days a year. A 2 kW size SPV plant was established. Under the project, 85 home lights were installed, along with 8 lights for street illumination.

Each home received one 9 W CFL (compact fluorescent lamp) for illumination purposes. Moreover, for community use, five extra points including a TV point and 8 street lights of 11 Weach were provided. A 2 kW PV power plant can easily cater to the total load of 0.944 kWp. Illumination for 5 h per day, 5 p.m.–11 p.m., had been fixed. The installation of SPV power plant was under the aegis of UNDP-DESI (United Nations Development Program - Decentralised Energy Systems India) for demonstration of power generation through renewable energy. Salepada is an example of community action coupled with the participation and involvement of the community at every step.

Kerala: Mundanmudy village. The solar lighting system in Mundanmudy village of Idukki district in Kerala, the largest installation of its kind in the world, has changed the life-style of the local people. Hundreds of houses (393 precisely) lined one after the other with bright solar panels in the village are quite impressive. Mundanmudy village is located at an elevation of 1500–2000 m near a reserved forest, with no access to the electrical grid. The connection only reaches the foothills, and even here due to the transmission losses, the light in the last few houses only glimmer. Till 1997, the entire population depended on kerosene lamps. But with the introduction of solar lighting system, the lighting dreams of the village have come true.

Uttaranchal: remote villages and hamlets. The government of Uttaranchal State prepared plans for electrification of all villages in the State by the end of 2007. All remote villages would be electrified through non-conventional energy sources. The state has a good mini hydroelectric potential and solar radiation in this region is also very good. The remote villages can therefore be electrified through Solar Household Systems (SHS). The selection of villages for electrification is done by Uttaranchal Renewable Energy Development Agency after obtaining “No Objection Certificate” from Uttaranchal Power Corporation Ltd.

Impacts and lessons learnt

People claimed to have benefited not only from the social point of view but also from the point of view of income generating activities. Vocational training for self-employment has been initiated. After sunset, the presence of light permits other activities such as sewing and handicrafts. Sewing machines are already in use for training the youth and women for income generating activities. In fact more such activities are on the way. Table 4 gives a brief overview of SPV and their benefits to the households in Sagar Island in West Bengal.

Case studies: other renewable sources

There is a long history of small hydro projects in India. The following two examples are illustrative.

West Bengal: Jaldhaka Hydroelectric Power Station. Jaldhaka hydroelectric power station, situated in West Bengal's Darjeeling district near Bhutan border, started operation with 2×9 MW generating units during the year 1967 and 3rd unit capacity 9MWcommissioned in the year 1972. This power station had been commissioned with additional 2×4 MW generating units in the year 1983.

Jammu and Kashmir: Hybrid Power System in Ladakh region. Ladakh is a remote region located in the Himalayas with very low population density. Small scattered loads and good availability of renewable energy resources like hydro, solar, wind and geo-thermal, makes the region ideal for renewable energy based decentralised power generation. At present hydro and solar energy play an important role in power generation and rural electrification in Ladakh. Hydroelectricity from small hydroelectric plants (installed capacity 8.5 MW) accounts for about 60% of the total electricity generation. About 7000 solar PV Domestic Lighting Systems provide electricity for lighting to about 25% of the households in Ladakh.

Impacts and lessons learnt

There is limited information on the performance, costs and impacts of wind, micro-hydro and SPV systems in India, These renewable and hybrid power projects have proved to be an effective environment-friendly way of producing electricity, and a viable alternative to electricity generated by thermal, large hydro and nuclear routes. They have benefited land owners, who had no means to irrigate and cultivate their otherwise barren land. Ample employment opportunities have been created for manufacture, installation, operation and maintenance of wind turbines, microhydro and hybrid systems. The above stated experiences have proved beyond doubt that such technologies not only deliver much-needed electricity, but also provide employment to a large number of people, and pave the way for economic prosperity. Hybrid systems combine two or more energy conversion devices, or two or more fuels that when integrated, overcome limitations inherent in either. These systems have been found to be very useful for meeting water pumping and small power requirements in de centralized mode in rural and remote windy areas of the country, which are un electrified or have intermittent electric supply. Such hybrid units offer greater reliability, especially for remote applications such as land-based while at the same time attempting to minimize the use of the diesel fuel. [8]

Other Major Impacts

Socio-Economic Benefits

Electrification has a major impact on rural society and can help in achieving following:-

-Higher productivity through electrical machinery, higher number of productive hours in theday through electric lighting

-Better access to affordable education and entertainment.

-Curbing the rural household expenses on fuel (charcoal, wood, kerosene,etc) and also controlling the environmental damage.

-Substantial reduction in smoke could improve both indoor air pollution and the health of Women on a daily basis.

-Reduction in subsidy bill could ease the pressure on Indian economy.

Commercial Benefits

-Since populations spread over a larger area, hence grid extension is a costly solution for connecting to remote locations.

-The maintenance of a large distribution network and high Transmission and Distribution (T&D) losses on such a network.

-DDG reduces or eliminates the "line loss" (wasted energy) that happens during transmission and distribution in the electricity delivery system

Climate Change Impacts

-Coal-based energy generation is water-intensive technologies thus has a larger effects of global warming and climate change as compared to DDG(s).

-Municipal Waste/Biomass dumped in open places emits Methane (CH4) which is part of GHG family but through DDG it can not only be used for productive use locally but could also assist in mitigate temperature rise.

-Long-term goal for Energy [r]evolution is to create energy equity via renewable energy.

-Decreasing the dependence on fossil fuel could cutting CO_2 while ensuring energy security, thereby reducing greenhouse gas emissions till 2020 from the 1990 level;

-Approximately two thirds of the energy from a traditional centralized plant is lost as waste heat. Distributed generation can be significantly more efficient by capturing this heat and putting it to use, thus bring down CO_2 emission.

-DDG helps in communities become more resilient to extreme weather events.

-Fuel cells are the lowest emitters when it comes to NOx, CO, particulate matters (PM10) and hydrocarbons (HC).

IV. NOTEWORTHY CONTRIBUTION IN THE FIELD OF PROPOSED WORK

Despite the growing demand of energy especially in semi-urban and rural areas, there is currently a significant gap between availability and demand of reliable power. Under the current centralized generation paradigm, electricity is mainly produced at large generation facilities, shipped though the transmission and distribution grids to the end consumers. However, the recent quest for energy efficiency and reliability and reduction of greenhouse gas emissions led to explore possibilities to alter the current generation paradigm and increase its overall performances. In this context, the best option is to replace the existing paradigm by decentralized and distributed generation where electricity is produced preferably through locally available resources, next to its point of use.

Ministry of Power and Ministry of New and Renewable Energy GoI have developed program under this category namely: Rajiv Gandhi Grameen Vidyutikaran Yojanja {Decentralized Distributed Generation (DDG)} and Net Metered based roof top systems etc. which has attempted to address the challenge of energy to all. But scheme design has flaws and therefore did not rolled out as substitute to centralized power generation and distribution, other than this scheme, no major work has been done in this field.

The acceptance of decentralized and distributed generation is growing and there is a need to develop a software based model to design and simulate a decentralized power generation system based on local requirement. The present research will therefore provide ways to not only the designing a sustainable Decentralized and Distributed Generation system but would also take into consideration the locally available renewable Energy resources to be explored first.

V. PROPOSED METHODOLOGY DURING THE TENURE OF THE RESEARCH WORK

1. Field visits will be organized to study the existing decentralized and distributed power generation systems.
2. Collection of primary & secondary data: Information required for research shall be obtained from primary as well as secondary sources.
3. Performance evaluation of the studied DDG systems
4. Study the various schemes of Government in support of DDG.
5. Application of Research tools: The results of the study shall be based upon, existing data available from different sources on the subject and a comprehensive field survey covering all aspects of the subject of research.
6. Develop a logical flow of activity chart for designing of DDG for any location considering energy load and load pattern.

7. Develop software based program for designing a DDG system based on present load with a forecasting for next five years.
   The evaluation of the resulted design would be done through simulation or at site.

VI. CONCLUSION

It is observed that not much success stories are available to demonstrate the effectiveness of Decentralized and distributed power management across the developing countries. It is a big challenge for developing new strategies and models for meeting the discrete and swelling demand of energy for countries like India. To introduce, demonstrate and deploy the new options for energy supply in their routine life would be difficult, but is the need of hour. So far attempts made for decentralized and distributed power are very discrete and mainly for areas where conventional or centralized power has not reached, where as our research focuses on providing an efficient solution through decentralized and distributed power for majority of the society even where centralized power is available. We are pursuing to develop integrated approach that includes both distributed and centralized elements with the options of various available energy resources. Renewable Energy technologies has made their presence in a big way and their role in planning a sustainable Decentralized and distributed power management system would be effective. Now time has come when Government of India also has to reframe the Electricity act 2003 in light of recent developments and proper place for Decentralized and distributed power management system.

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