Centralized and Distributed Generated Power Systems-A Comparison Approach

White Paper Team

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Proposed Objective

- The objective of this presentation is to identify the strengths and weaknesses associated with Centralized Generations (CG) and Distributed Generations (DG) infrastructure for the future electric grid system.
- Criteria for analysis include:
  - To what extent are economies of scale still relevant for CG/DG?
  - Which is the most cost-effective combination of DG and CG infrastructure?
  - To what extent does DG or CG improve system resilience to unforeseen events?
  - What is the most attractive combination of DG and CG infrastructures to maximize system resilience due to unforeseen events?
  - To what extent does DG or CG improve sustainability i.e. decrease emissions and diminish other environmental impacts?
  - What is the most attractive combination of DG and CG infrastructures to maximize system sustainability?

Approach to Solving Proposed Objectives

- The following summarizes the approaches to the prior posed questions:
  - In consideration of the economies of scale involved for the CG and DG system, combination of both CG and DG would better prove to attain a better scale.
  - Provided that consistent electricity and heat loads are available, proper DG penetration in CG could attain the lowest cost technology.
  - Since the resilience of a power grid is dependent on power consumption, a DG system can be said to be of better resilience than a CG system.
  - To eliminate emission, the mixture of DG and CG is pertinent to be deployed.
  - Sustainability could be achieved by elimination of emission. Wind, solar, and biomass making up the DG can also go along way to improve sustainability. However, the limitation of DG during extreme events could also be limiting. The role of CG, if elimination of emission is possible, is considerable. Combination of the CG and DG therefore is open for discussion.
- To be incorporated in the decision support tool for analysis and determination of optimal mix of DG and CG, the following tools are proposed:
  - Decision support tools - AHP, game theory, and sustainability measure
  - Optimization methods based on goal programming with stochastic programming under uncertainty constraints, where resilience, reliability and power quality are constraints.
- This presentation also plans to provide a national roadmap to guide towards identifying the right path forward in terms of which combination of DG resources and CG would make sense.

Introduction

- There are many reasons for considering the extent for which a planning and operation decision should be based in a power system network that may comprise combination of CG and DG or either.
- To embark on development of the grid's flexibility for the future, research effort is therefore needed to evaluate the potentials of available options in CG/DG amidst the increasing power demand and uncertainties.
- To this end, this presentation proffers criteria for analysis of DG and CG, it takes into consideration the economic of scale, cost implication, reliability, sustainability and resiliency as constraints in selecting or building CG/DG grid's infrastructure as well as the possibility to combine the systems for optimal performance.

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CG Definition in Electric Grid

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- Central generation or CG is electric power production by central station power plants most of them using large fossil fired combination of nuclear boilers to produce steam that drives turbine generators. In some cases, large hydro and coal plants are also used.
- CG plants are so large that they require large infrastructures which are expensive to manage.
- CG Plants are susceptible to unreliability and instability under unforeseen events and hence can be vulnerable to attacks.
- CG limitations are often low efficiency and environmental impact as well the stability to sustain them.

DG Definition in Electric Grid

- Distributed generation or DG is any power generation built near to consumers.
- DG sources could include only small-scale, environmentally friendly technologies installed on and designed primarily to serve a single end-user’s site.
- Properly planned and operated DG can provide consumers and society with a wide variety of benefits, including economic savings, improved environmental performance, and greater reliability.
- The DG can be more economical and yield reliability at a price.

Criteria for CG/DG Comparison

- The criteria for CG/DG comparison presented here will involve economical scale study of DG relative to CG, and consider which is the most cost-effective combination to accommodate new markets.
- Another criteria for CG/DG comparison is to evaluate the resiliency of the combined infrastructure.
- Sustainability impact of either or both DG/CG as it relates to diminish radiation, decrease emissions, and reduce environmental effects.
- This presentation therefore leads to provide a national roadmap to guide towards identifying the right path forward in terms of which combination of DG resources and CG would make sense.

Building a Flexible Future Grid

- In an attempt to build a feasible future grid that will meet the growing demand of the population worldwide. Urgent resources that are cost effective, environmental friendly and guarantee sustainability as well as resilient to attacks by unforeseen forces are needed. The infrastructure of the future grid will determine CG/DG or combination is of interest.
- To provide working guide, institutional arrangement of the presentation provides criteria for evaluating the options available. These options are:
  - Economic of scale
  - Sustainability
  - Resiliency
- To this end, the analysis and findings will lead to National Research and Development, and Roadmaps for development of the flexible infrastructure.

CG and DG Values, and Recommendations

Value	Distributed Generations	Centralized Generations	Recommendation for CG and DG options
Continuous Power	Operated to allow a facility to generate some or all of its power on a relatively continuous basis. Important DG characteristics for continuous power include: ▪ High electric efficiency, ▪ Low emissions.	Though operated to provide continuous power, its characteristics results in: ▪ Low electric efficiency as a result of high losses at the transmission system ▪ High emissions	For continuous power production, more DG need to be penetration in CG based networks to reduce emissions and increase efficiency.
Premium Power	It provides electricity service at a higher level of reliability and power quality than typically available from the grid.	Provision of power at low reliability and power quality cannot be guaranteed due to inherent high power losses.	Providing premium power would also need DG penetration in the CG network leading to better reliability and low losses.
Cost	Low variable cost Low maintenance costs	High variable cost High maintenance cost	With respect to cost, DG based networks is preferable.
Peaking Power	Operated between 50-3000 hours per year to reduce overall electricity costs.	It is operated unintermittently at various peak powers.	Combined CG and DG.
Resiliency	More resilient since it serves low power demands continuously.	Less resilient but serves high power demands continuously.	Combined CG and DG.
Sustainability	Sources of power makes it more sustainable	Sources of power results in less sustainability	More of CG is preferable.

Associated Issues of DG/CG Systems

- Economies of scale: the advent of steam turbines made it possible to increase the size of the turbines while decreasing the marginal cost of electricity production.
- High energy efficiency: gains in efficiency were achieved through larger facilities capable of handling higher pressures and temperatures in steam used in electricity generation.
- Innovation in electricity transmission: the use of alternative current instead of direct current permitted to transmit electricity over long distances with a significant loss reduction.
- A search for reliability: so as to increase the reliability at the customer's end, large electricity production facilities were connected to the transmission networks.
- Environmental constraints: the use of transmission networks made it possible to relocate the generation facilities outside the city centers thus removing pollution due to exhaust from coal fired plants.

Assessment of Economical Issues Facing CG and DG

- Overall goal here is to develop cost analysis of building and installing DG leading to
  - Distributed load
  - Cost of technology is low
  - Provision of value based locational marginal pricing
  - Improve value of reliability by minimizing cost using controls in a distributed form
- The use of CG/DG in sustainability and resiliency affects cost implication of renewable energy resources resulting in:
  - Low emissions, thereby enhancing better quality of life
  - Less resilience, with DG having the capability of self-healing, renewal of resources with value added cost.

Assessment of Technical Issues Facing CG and DG

- In network security, the size will be limited since a DG has to comply with set standards rather than to simply meet supply security at the pre-reconnection point which will require more controls options for better security though at higher budgeted cost.
- Voltage levels one feature of radial type system is that they supply a number of distributed consumers economics suggest that they taper along their length and hence DG at such location will increase local voltage level.
- Network stability issues under fault condition the system dynamics may cause instability depending on the characteristic of DG. If this occurs, appropriate control system has to be included at a cost to overcome the instabilities.
- Renewable energy resources which would lead to sustainable electricity supply system given these resources could be harnessed to power distributed generation and reduced incurred power consumption cost.
- These have lots of advantages including its non-depleting ability, indigenous not dependency on importation, non-polluting with some emission produced during manufacturing and end of life disposal, diverse and complementary in their time dependency.

Analysis of Economies of Scale in CG/DG

- As power demands increase, the ability of the power grid to enhance power reliability becomes indispensable. To ensure power system resiliency, sustainability and reliability, the present grid has diversified the technologies of power production.
- This technology has necessitated the demand for growth in the number of distributed generations. Same could be said about the centralized generations. However, due to the higher installed capacity of most CG, it becomes more expensive increasing the number of CG operating in a region of power demand.
- Hence, as power demands increase it costs less installing a DG to meet the increased power compared to CG.
- Recall also that the transmission of power cost in CG makes it highly non-economical when there is a new power production facility to be installed. A DG on the other hand has no need for a transmission network thereby eliminating losses in transmission.
- Therefore, it becomes apparent by installing new power capacity plants; a DG has better economies of scale than a CG.

Analysis of Cost Implications for CG and DG

- With the technologies involved for centralized generation and distributed generation, it becomes essential to compare the costs that could be incurred in a typical design layout of both CG and DG.
- Since distributed generation will continue to be a potential source of viable energy that enhances uninterruptible power, expanding the role of DG in the power grid of the future could totally be based on whether the costs of DG is lower than DG.
- For capturing small niche market of power demands, by producing power directly at the site of usage, power by distributed generations would be more valuable at or very near the retail price of generated electricity since it displaces utility-provided power.
- A small power generation project like the DG is also less likely have negative impacts with land uses. This goes a long way to install DGs more than CGs.

Cost Implications Breakdown for CG and DG

Cost Component	Centralized Generation (CG)	Distributed Generation (DG)	Recommendations
Cost of Capital	Lower Cost per unit	▪ Higher cost per unit ▪ Saved cost of system design due to reduced capacity ▪ Saved cost of system design due to use of waste heat in cogeneration	▪ With consideration of either CG or DG serving same power demands. It becomes pertinent that combined system would lead to optimal cost. ▪ Capital cost which tends to be higher for DG as compared to DG for same power production rating goes a long way to using more of DG in a CG based networks. ▪ This approach would lead to reduced overall cost of a power grid system with combined DG and CG grid.
Fixed Operation and Maintenance Cost	Higher	Lower	
Variable Operation and Maintenance Cost	Lower	Higher	
Fuel	Same as DG	Same as CG	
Transmission	High voltage transmission is mandatory Far higher unit cost compared to DG	Only distribution required Unit Cost is far lower than CG	
Expense for unserved energy	High	Low	

Economic Pricing Benefits for CG and DG Systems

- DG provides maintenance and improves cost incentive for generators additions.
- Benefit cost allocation to DG is an advantage for determining the economic of scale of DG.
- Unlike the CG, overall cost may not allocate tax and market pricing.
- Benefit allocation due to the technology development leads to loss reduction .
- Associate price and benefit is also a rationale for selecting DG.

Resilience of CG and DG System

- Resilience is the ability of a system to respond and recover from an event. In other words, it is the response of the system to recover from a catastrophic event like hurricane, earthquake etc.
- The resilience prevalent in either a CG or DG system is the property associated with the system such that increased or decreased load demand is appropriately compensated with increased or decreased supplied power. Resilience required in a CG is therefore not the same as that necessary for a DG.
- This is because the load demand required for a CG is higher than a DG. In compensating this higher load demand for a CG, recall that that the installed capacity for the CG is greater than DG.
- Resiliency in DG systems is high due to self-healing capability as compare to CG. Faults cases in CG have less severe impacts on the grid since they serve smaller regions that CG.
- In extreme cases of natural disasters like hurricane, tornado etc leading faults in the grid, a CG based network would highly be affected with less effect on DG

Measures of Resilience in CG/DG

- Resilience metric is defined as:

$$R(x, u) = \int_t^n \left[\sum_{i=1}^n c_i f_i(x, u) \right] dt$$

- This metric could be used as assessment of the resiliency of DG or CG systems where $f_i(.)$ is the routine task, such as power supply and transmission transactions, and/or communication services, with weight coefficient c_i as an associated cost at a given time scale; x and u are the state and control variables, respectively.
- Since DG is more resilient than CG, therefore a higher metric of resiliency is understandable in a grid with CG and DG networks.
- Resiliency in DG systems is high due to self-healing capability as compare to CG.
- Faults cases in CG have less severe impacts on the grid since they serve smaller regions that CG.
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Reliability Assessment Index-Expected Unserved Energy

- EUE - Measure of transmission system capability to continuously serve all loads at all delivery points while satisfying all planning criteria.
- Required information for computing EUE include
  - Frequency of each contingency (outage/year)
  - Duration of each contingency (hr/outage)
  - Unserved MW load for each contingency
- EUE = sum of all the probabilistic weighted unserved MW for each contingency.

$$EUE = \frac{\sum_{i=1}^{N}\sum_{y=1}^{Y}\sum_{d=1}^{D}\sum_{h=1}^{H} E_h}{N_h}$$

- Where:

EUE = Expected Unserved Energy (MW-hours/hour)

N = the number of Monte Carlo simulations for the period, which is typically one year using hourly level of granularity

Y = number of years in the study

D = number of days in each year that are simulated

H = number of hours in each day that are simulated

$\mathbf{E_h}$ = the amount of unserved energy for this hour (in megawatt-hours)

$\mathbf{N_h}$ = the total number of hours simulated in the Monte Carlo study.

Reliability Assessment Index-Loss of Load Probability

- **Loss of Load Probability (LOLP)** in units of *percent*, measures the probability that at least one shortfall event will occur over the time period being evaluated.

$$LOLP = \frac{\sum_{i=1}^{N} S_e}{N}$$

- Where:

LOLP = Loss of Load Probability (%)

$\mathbf{S_e}$ = Simulation in which at least one significant event occurs. A significant event occurs when load and operating reserve obligations exceed resources including contingency operations (or event threshold limits).

N = the number of Monte Carlo simulations for the period, which is typically one year.

Recommendations of Factors Affecting Resiliency in Combined CG and DG

	Factors	DG	CG	Recommendations
1	Reliability	Low reliability but has power output limitation	High with more output power	Combined DG and CG with more DG in the grid
2	Stability	Good stability	Better stability	Combined DG and CG with more CG in the grid
3	Faults in the grid	Less severe impact	Severe impact	Combined DG and CG with more DG in the grid
4	Extreme unforseen events	Less impact	High impact	Combined DG and CG with more DG in the grid

Enhancing the Reliability of Power Grid through CG/DG

- As CG or DG systems continue to grow in size and capabilities, the current state of the art in power system reliability is being pushed to its limit.
- While power engineers try as much as possible to ensure that there is constant power availability to users, considerations of some natural disasters like earthquake, hurricane, tornado, snowflakes continually mitigate the availability of continued power being supplied to these consumers.
- A distributed generated system on the other hand has its location closer to power users. This architecture there needs not a transmission network. Hence, losses inherent in DG architecture are far less than CG system leading to more reliability for a DG-based grid.
- Based on the multi-dimensional factors that affect DG and CG operation, we revise here reliability performance metric which is to be incorporated in decision support tool for analyzing and determining the operational merits of DG and CG.

Sustainability in CG and DG

- Sustainability of a power system network is the capacity of the power grid to withstand load requirement and yet meet the power consumers need.
- Sustainability is also the capability of critical infrastructures to persist functions or services in a longer term.
- Evaluations of CG and DG shows that more installation capacity is required for a CG than a DG since the CG has more power demand on it than a DG (obviously not group of DG).
- Considering the cost of installation and ease of resource availability, DG systems could very well serve as better option to meet the increasing needs of consumers.

Sustainability in CG and DG (Contd)

- Aim of sustainability in CG and DG is to address:
- Environmental protection such as it concerns climate change and conservation resources. How each of this will contribute to electric power system sustainability is the basis of CG and DG comparison.
- Health and safety in environment: This is an aggregate comparison to be undertaken depending on the location and type of technology use for DG.
- Security of Supply: A need arises at looking at the medium to long term availability or the diversity of fuel options from producing the power; consideration of low cost of availability reduction nor loss of grid or plant and also adaptability of DG to different fuel and resources.
- Economic impact in terms of job creation, increase in production of services, innovation, flexibility and increase knowledge.

Sustainability Effects in CG and DG

- Sustainability effects in CG is based obsolete technology, but power industry regulations largely derive from the unquestioned belief that central generation is optimal. In meeting the world's growing needs for electric power centralized generation will severely tax capital markets, fossil fuel markets and the global environment.

However, sustainability in a DG system would aim at addressing the following:

- Energy consumption reduction.
- Reduction of sources of energy waste.
- Minimization of energy production pollution.
- Minimization of life-cycle costs of renewable energy resources.
- Sustainability in CG and DG Systems.

Measure of Sustainability in CG/DG

The sustainability metric could be defined as:

$$T(S_r) = P(S_r)(f(S_r))^{-1} = [\sum_{j \epsilon S_r}^{n} P_j] [\sum_{j \epsilon S_r}^{n} P_j \sum_{j \notin S_r}^{n} \lambda_{jr}]^{-1}$$

- This metric measures the level of sustainability of either a DG or CG networks where contingency *j* at certain load level is characterized with probability *pj* and transition rate is from and to other system states *j, r*.
- A higher metric of sustainability is understandable in a grid with CG and DG networks
- The role of renewable energy to meet increased demand while at the same time reduce its impact on environmental pollution caused by emission is required. Current legacy system fitted with CG has been outgrown.
- Electric grid of the future is to consider other energy sources. Bearing in mind that renewable energy resources (RER) is an attractive choice with advantages and disadvantages.
- The question now is how much RER (or DG) will meet the demands for sustainability of the quality of life? CG on the other hand meets demand but has continued to reduce the quality of life due to emission.

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Power Quality Issue in CG and DG

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- Power quality is the set of limits of electrical properties that allows electrical systems to function in their intended manner without significant loss of performance or life.
- The term is used to describe electric power that drives an electrical load and the load's ability to function properly with that electric power. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all.
- The inclusion of power quality study to assessing the role of DG fundamental criteria that include: steady state voltage rise, voltage fluctuation, voltage dip, generator start-up and static voltage stability

Measures of Power Quality in CG and DG

- CG networks are over long distances as compared to DG networks. It therefore follows that a CG network system is more prone to voltage fluctuations, voltage dip and instability when compared to a low ranger DG systems. This, however, does not limit power quality challenges to a CG system.
- DG networks are excellent power grid networks that can be used to address a grid power quality challenges by the incorporation of storage systems (flywheel, super-capacitors etc.) and equipment usable as power conditioner.

Indices for Measuring Power Quality

Index	Definition	Main applications
Total harmonic distortion (THD)	$\left(\sqrt{\sum_{i=2}^{\infty} I_i}\right) / I_1$	General purpose; standards
IT product	$\sqrt{\sum_{i=1}^{\infty} w_i^2 I_i^2}$	Audio circuit interference; shunt capacitor stress
Crest factor	V_{peak} / V_{rms}	Dielectric stress
Unbalance factor	$\lvert V_- \rvert / \lvert V_+ \rvert$	Three phase circuit balance

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Enhancing Power Quality through DG

- *DG Grounding Issue:*

A grid-connected DG, whether directly or through a transformer, should provide an effective ground to prevent un-faulted phases from over-voltage during a single-phase to ground fault.

- DG can reduce power losses and defer utility investment for network enforcing; on the other hand, the DG interacts with the power quality (PQ) of the distribution network.
- DG can introduce several disturbances causing a reduction of PQ levels, such as:

- Transients, due to large current changes during connection

or disconnection of the generators.

- Voltage fluctuations, due to cyclic variations in the generator output powers;
- Long-duration voltage variations, due to generator active and reactive power variations;
- Unbalances, due to single-phase generators.

Sustainability Effects in CG and DG (Contd)

	Factors	DG	CG	Options
1	Emissions	Low but has power output limitation	High with more output power	Combined DG and CG with more DG in the grid
2	Power Quality	Good Power quality	Better power quality	Combined DG and CG with more CG in the grid
3	Quality of Service	Better quality of service	Less quality of service co	Combined DG and CG with more DG in the grid

Standards for Enhancing Interoperability and Security in CG and DG

- To enhance the proper selection of DG or CG in the future grid, standards and operational requirements such as interoperability has to be developed with approved standards integrating CG and DG. This presentation has provided part of the scenarios for deciding on whether more DG or CG should be used in future selection of grid regulation for better operational security.

Security issue in CG and DG has necessitated the following standards

- The Institute of Electrical and Electronic Engineers (IEEE) in 1999 started devising a universal interconnection standard for a distributed generation
- This was necessitated given the fact that major barriers or challenges posed by DG was as a result of inappropriate interconnection between the DG and a power system network.
- By the winter of 1999, IEEE came up with the standards for DG and termed it IEEE P1547. Its purpose is to set up a uniform standard for distributed generation of 10MW or lesser.
- These standardized requirements are relevant to the performance, operation, testing, safety, and maintenance of the interconnection.

- Distributed generations can be depicted as attractive energy resource solutions whether in the near future or long-term when the energy supply and capacity challenges becomes critical.
- There are numerous benefits in distributed generations. Some of such benefits reiterated include: increased power supply efficiency, reduced line losses, greenhouse gas emissions reduction, decreased distribution and transmission infrastructural spending.
- With all these benefits coupled with enhanced security, stability and flexibility of the distributed generation, it thus becomes vital to evaluate the roadmap for distributed generations.

Roadmap Research: Development of the Infrastructure for the Future Electric Grid (Contd)

- Identification of the Roadmap: A National Research Agenda for Development of the Infrastructure for the Future Electric Grid will include:
- Determination of costs and trades off between CG and DG with respect to control costs, life cycle analysis, and protection and maintenance
- Introduction of resilience metric into power systems planning and operation which will help to evaluate stability margin, demand response, reliability issues of the system under resilience.
- Determination of sustainability metric into power systems planning and operation will help to determine emissions effect, as well as power quality issues of the system under sustainability.
- Determination of value added CG and DG incentives for renewable energy storage, plug-in cars, ramping, and price response, and demand management in the grid.
- Better use of new tools like phasor measurements, time of day pricing, and other intelligent infrastructure for system support
- Develop better and faster algorithms which include decision support tools, adaptive predictive model and state estimation for better management Development of new curriculum and education to provide human capacity training and planning.

Research Topics to Aid National Roadmap Agenda

- Impact studies and analysis, which include reliability, stability, and network congestion.
- Mitigation of market power.
- The economic incentives to owners of clean DG technologies and the reduced health risks to society.
- Reduced Security Risk to Grid.
- Voltage Support to Electric Grid.
- Land Use Effects: The value of reducing "foot-print" or space needed by generation, transmission and distribution infrastructures.
- System Losses.
- Combined Heat and Power/Efficiency Improvement.
- Consumer Control.
- Ancillary Services. The value of providing spinning reserve, regulation, or other ancillary services with respect to the cost-benefit analysis study.

Strategic Approach to National Roadmap

Roadmap	Factors	Combined CG and DG	Suggested Period of Roadmap
Research	Cost	Combined CG and DG will determine costs and trades off between CG and DG with respect to control costs, life cycle analysis, and protection and maintenance. Mixture of CG and DG will determine incentives for renewable energy storage, plug-in cars, ramping, and price response, and demand management in the grid Better use of new tools like phasor measurements, time of day pricing, and other intelligent infrastructure for system support is attained with mixed CG and DG.	Short term
	Economic of Scale Service Enhancement	The economic incentives to owners of clean DG technologies combined with CG leads to reduced health risks to society.	Short term
	Computational tools	Develop better and faster algorithms which include decision support tools, adaptive predictive model and state estimation for better management and planning.	Medium term
Resilience	Reliability Stability Quality of Service	Appropriatre resilient metric applied to the power systems planning and operation would help to evaluate stability margin, demand response, reliability issues of the system under resilience for a more robust CG and DG.	Short term

Strategic Approach to National Roadmap (Contd)

Roadmap	Factors	Combined CG and DG	Suggested Period of Roadmap
Sustainability	Emissions	To eliminate emission, the mixture of DG and CG is pertinent to be deployed.	Long term
	Environmental Impact	Land Use Effects - The value of reducing space needed by generation, transmission and distribution infrastructures is promoted leading to reduced security risk to the grid for the CG and DG.	Short and Long term
	Power Quality	DG can reduce power losses and defer utility investment for network enforcing better than CG; on the other hand, the DG interacts with the power quality (PQ) of the distribution network.	Long term
Institutional Arrangement		Land use in CG and DG comprises the institutional arrangement. This is aiming at addressing economic of scale, cost resiliency and sustainability benefits in combined CG and DG would better lead to institutional arrangement.	Short, medium and long term
Human Capacity Building		This work is aimed at developing new curriculum and education to provide human capacity training.	Short, medium and long term

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Conclusion

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- This presentation has been reviewed based on different technology, options for serving power demands. In the future, flexible grid DG based on renewable energy has proven to be of interest to utility, government and independent power producers (IPP) due to its affordability and flexibility to penetrate the grid's networks.
- Firstly, CG continues to be attractive due to its availability for large power production and some areas. The challenge remains to what extent can we co-optimize CG integration in the future grid? This presentation addresses this question. It also summarizes the various viewpoints in terms of economic of scale or index for comparing DG and CG that will justify and develop a policy that will promote economic of scale, optimal cost, resiliency, and sustainability.

Conclusion (Contd)

- Secondly, the issue of resiliency is caused by unforeseen events which have been discussed to value CG and DG. This purpose is to optimize the coordination of CG and DG that will provide a resilient source of power in the future grid. The resilient aspect of this presentation also concerns the issue of reliability and power quality of DG and CG. The next attribute for comparison involves the development of DG or CG based sustainability. Issues of DG to provide cleaner environment and reduce emissions are discussed. The disadvantages of DG resources are also compared with CG in the presentation.

- Therefore, based on the analysis in the presentation challenges arise to provide opportunity for research and development and this has helped to shape or direct a national roadmap for development of a combined DG and CG based networks.

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