INTEGRATED DISTRIBUTED ENERGY RESOURCES AND MICROGRID CONCEPT IN THE EVOLVING POWER SCENARIO.

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ABSTRACT:

Though the distribution system plays a primary role in grid evolution due to its size, value, diversity and direct interface with the customer, but owing to resource constraints there is a need for gradual transformation where portion of distribution systems are reconfigured to deliver maximum value for stakeholders. The microgrid concept supports the model as it enables portion of distribution system to deliver customized levels of service including reliability, efficiency and use of distributed generation including renewable resources. Microgrid control concept, related protection aspects, DER power quality issues and benefits of Distributed Energy Resources and microgrids are discussed in the paper.

Index Terms – DER, Distributed Generation, microgrid, MGCC, DMS, LC, MC, point of common coupling, K-rated transformer

I. INTRODUCTION :

The electric power industry is undergoing a dramatic change due to deregulation thus introducing competition among electricity providers who can distinguish themselves by price, services, power quality and other factors. The new electric power system will feature advanced technologies and services that can be used on site or located in close proximity to the load instead of depending solely upon large central station generation and transmission. In the recent times there is emphasis on usage of non-conventional type distributed energy resources (DER) integrated in the form of microgrids designed to generate power locally at the LV distribution level and feed it to the consumers. DERs are systems that produce electrical power at the site where the power is needed. The following issues in power sector have become the main reason behind this change:

. Due to increase in load demand leading to mismatch between generation and load,
. Congestion in existing power transmission and distribution systems
. Geographical, environmental and political constraints
. Emergence of micro-generators with low voltage and power rating with combined heat and power (CHP) applications leading to high energy efficiency, ecological benefits and low costs
. Privatization, deregulation and competitive power markets

Distributed Generation means generation connected to the distribution network or on the customer side, the size not more than 20 MW and 24KV voltage levels. The main idea is that while the consumption of the end–users increases, additional electricity is taken from the distribution network and when the consumption decreases the generation unit may provide electricity to the network. Using a variety of advanced modular generating technologies, Distributed Energy resources (DER) plants supply base load power, peaking power, backup power, remote power and in some cases supply higher and more reliable quality power.

II. LIST OF POTENTIAL BENEFITS FROM THE USE OF DER:

Sl No	Benefit type	Definition
1	Generation Capacity Deferral	The financial value of deferring or avoiding a capital investment in central generation capacity
2	Transmission Capacity Deferral	The financial value of deferring or avoiding a capital investment in transmission system capacity
3	Distribution Capacity Deferral	The financial value of deferring or avoiding a capital investment in distribution system capacity
4	Voltage Control/VAR production	The value (or potential revenue) of providing voltage/VAR control
5	Environmental/Emissions	The value of emissions offsets or other environmental benefit
6	System losses	The value of the energy saved through reduced resistive system losses
7	Energy savings	The monetary savings in energy production costs
8	Reliability enhancement	The value of outage costs that can be avoided
9	Power Quality	The value of improving the quality of the power at or nearby customer sites.
10	Demand Reduction	The cost savings from reducing peak monthly customer demand
11	Combined Heat and Power	The cost savings from utilizing waste heat from the DER in customer applications.

III . MICROGRID CONCEPT:

A microgrid is an integrated energy system consisting of interconnected loads and distributed energy resources that can operate in parallel with the grid or in an intentional island mode. The integrated distributed energy resources are capable of providing sufficient and continuous energy to a significant portion of the internal demand. The microgrid possesses independent control and can island and reconnect with minimal service disruption. Configuring an energy delivery system in this manner provides flexibility in how the power delivery system is configured and operated and provides the ability to optimize a large network of load, local distributed energy resources and the broader power systems.

Microgrids provide six complementary value propositions:
1) Reduced cost: reducing the cost of energy and managing price volatility
2) Reliability: improving customer and system reliability
3) Security: increasing the power delivery system resiliency and security by promoting the dispersal of power resources
4) Green power: helping to manage the intermittency of renewables and promoting the deployment and integration of energy efficient and environment friendly technologies
5) Service Differentiation: providing different levels of service quality and value to customers segments at different price points
6) Power system: assisting in optimizing the power delivery system including the provision of services.

IV. MICROGRID TECHNOLOGY:

Some of the technologies that are going to be utilized in microgrids are discussed in brief.

Wind Turbines: Typical systems range from 30KW for individual units to 2MW for multiple units. Either synchronous or induction generators are used. The major disadvantage of wind power is variation in power quality due to changes in wind speed and low electrical efficiency of 25%. During normal operation directly connected generator may cause some increase in the flicker levels and in the variation of active power flow. With modern inverter technology allowing variable speed systems the power output can be held relatively constant independently from the wind speed variations.

Photovoltaic: Photovoltaic (PV) systems convert the sunlight directly to electricity and is particularly useful for sites remote from the distribution network. The maximum theoretical efficiency that can be attained by a PV cell is 30%. PV units are connected to the network applying inverter. This kind of arrangement will potentially cause harmonics unless filtered. On the other hand the inverters of PV system could operate, in future, as active filters to reduce low order harmonics in distribution system.

Micro-turbines: These are mechanically simple, single shaft, high-speed devices with primary fuel as natural gas or liquid fuels which permit clean combustion. The pressure of the air increases after it passes through the centrifugal compressor and there is temperature rise of the compressed air as it passes through the heat exchanger. Thereafter the air enters the combustion chamber where it is mixed with fuel and burned. The high temperature gases thus produced are then expanded in the turbine to produce mechanical power which drives the permanent magnet to produce electrical power. As the speeds of these microturbines are very high the frequency of the output voltage is of the order of few KHz. So the output voltage is to be converted to a suitable DC value using a converter and then converted to AC at grid frequency.

Combined Heat and Power (CHP): It is an integrated energy system delivering both electricity and useful heat with natural gas as the fuel. The CHP generators are placed nearer to the local heating loads to maximize overall energy efficiency.

Fuel Cells: Though currently expensive they offer high efficiency and low emissions. High temperature solid oxide and molten carbonate cells have been demonstrated and well suited for microgrid application.

V. MICROGRID CONTROL SCHEME :

A typical representation of microgrid with several micro-sources, loads, storage elements, control and management equipment is as shown where

MGCC- Micro grid Central Controller
DMS- Distribution Management System
LC-Load Controller
MC- Micro source Controller.

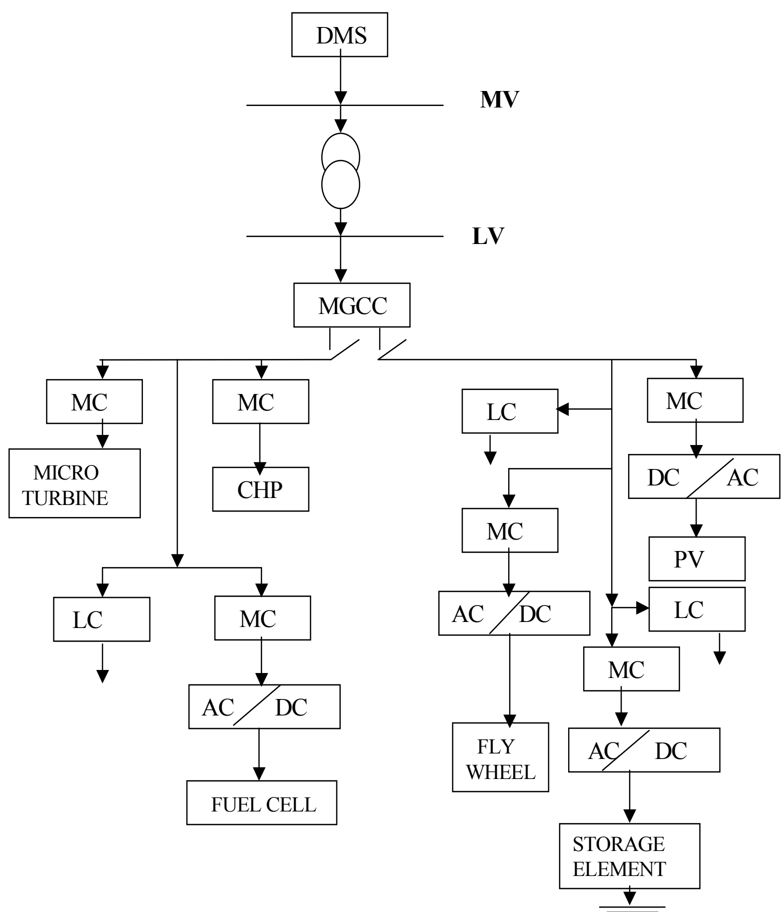

Fig 1 : Microgrid Control Schematic

The entire microgrid is controlled and managed by Microgrid Central Controller (MGCC) installed in the LV side of MV/LV sub-station. In normal grid connected mode, MGCC collects information from micro-sources and loads. This information is required for load forecasting studies, economic scheduling of distributed generators, demand side management functions and interfacing with MV side DMS.
In emergency mode, MGCC send control signal to micro-source controller (MC) to change output power of microgenerators as it is necessary for frequency control of the islanded microgrid. The load controller (LC) will control the switching-on and switching-off the loads, whereas microsource controller will control the active and reactive power production of the micro-generators.

VI. POWER ELECTRONIC CONVERTER AS GRID INTERFACE:

DER sources such as variable speed wind turbines, PV arrays, fuel cells and battery energy storage systems generate voltages that cannot be directly connected to the grid. The power electronic converter is the key interface that matches the electrical characteristics of the DER to the requirements of the grid including frequency, voltage, control of active and reactive power, power quality etc. The control concept of distributed generation with interconnection of different sources with the grid by intelligent use of converter inverter set, converter etc is presented. The converter can be conceptualized as :

Converter_ac : defined as AC/DC/AC converter
Converter_dc : defined as DC/AC converter

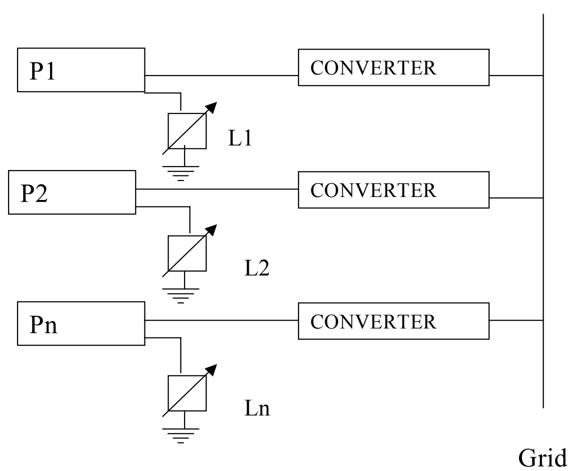

Fig 2 : Interconnection of DER to the grid

If output of plant P1 is ac then AC/DC/AC converter and if plant Pn is dc then DC/AC converter is to be used. The characteristics of the converter which are significantly different than those of a synchronous electrical machine may present uncertainties to network engineers and planners. On the other hand, the flexibility and adaptability of the power electronic converter present opportunities to increase the value of distributed energy generation by providing ancillary services or benefits such as backup power, power quality improvement, pf control and demand management functions.

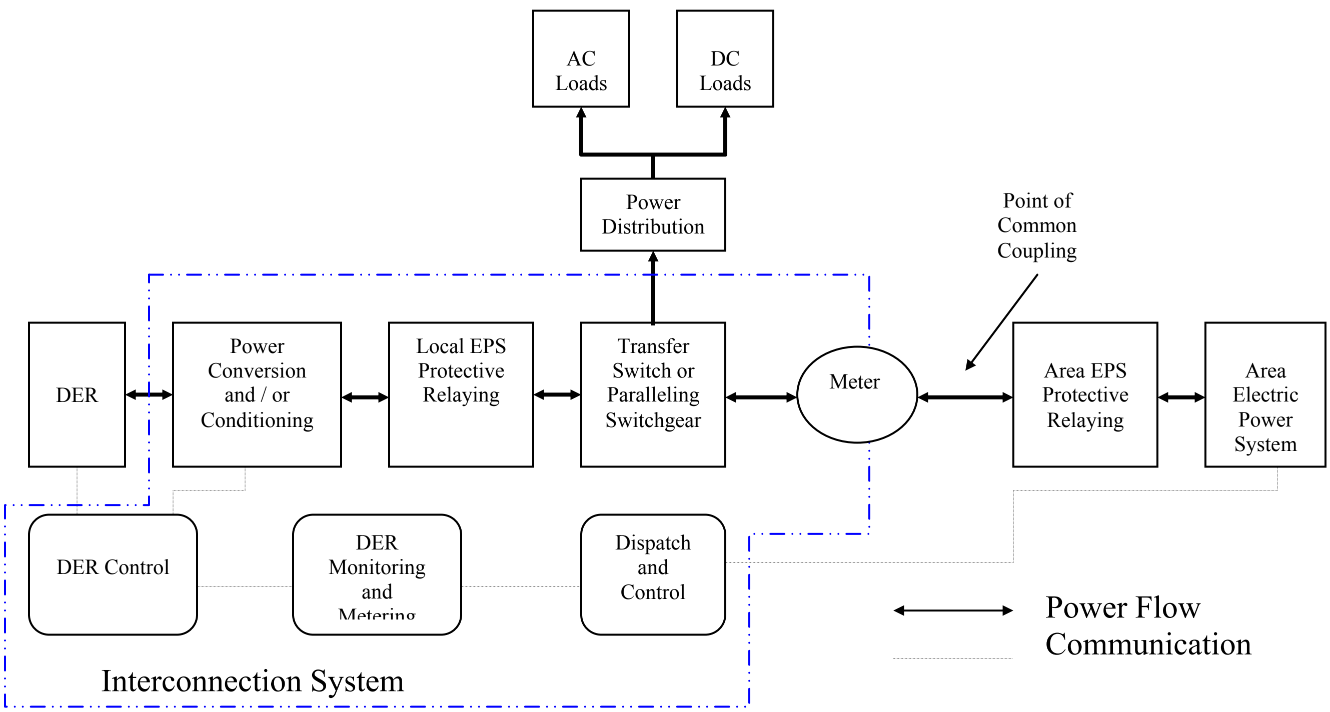

Figure – 3 Interface between a distributed energy source and the electric power system

Power Quality Aspects: A power quality concern of DER converters is that it injects direct current into the grid either due to offsets in internal control loops or a component failure increasing saturation of magnetic components such as distribution transformers which cause increased power distortion. Special K-rated transformers need to be used which are designed to have lower eddy current losses .

Mathematically, $$K = \sum_{h=1}^{h=\infty} I_h(pu)^2 . h^2$$

where $I_h(pu)$ is harmonic current in per unit value and h is the harmonic order

K factor rating applied to transformer is an index of transformers ability to supply harmonics (% THDi which is total harmonic distortion in current) at its load current while operating within its temperature limits. K rated transformers are only intended to survive in harmonic rich environment and do not mitigate harmonic voltage and current. IEEE C57-110-1986 is prescribed procedure used to derate the transformer loading based on specific harmonic content.

DER interconnection standard limit dc current injection to a low level, typically 0.5% of the DER rated current. The simplest and the most certain method to avoid dc injection is to insert a line frequency isolation transformer at the output of the DER converter so there is no path for dc current into the grid. However the transformer adds significant cost, size and weight. Hence techniques have been developed to precisely regulate dc offset in the converter to minimize dc injection during normal operation and to detect dc injection and de-energise the converter if a failure occurs.

Typically the converter is operated as a current source that feeds sinusoidal current into the grid. A combination of active waveform synthesis and passive filtering allows individual converters to produce currents with low harmonic distortion that meet relevant power quality standards such as those in EN 1000-3-2. Concerns remain about possible cumulative contribution of multiple converters to grid voltage distortion at high levels of DER penetration.

Grid paralleling and transfer switching : DER converters synchronize to and track the grid frequency and in most cases are operated at a fixed power factor that is close to unity. This meets interconnection standards that require that the DER shall not actively regulate the voltage at the point of common coupling (PCC). The power converter's ability to control frequency, phase and magnitude of the output current allows it to easily parallel the DER to the grid with essentially no synchronizing transient and in general the paralleling switchgear is much simpler than that required for a synchronous machine generator.

The converter must seamlessly switch between a current control mode that follows the grid voltage and frequency and a stand-alone control mode that regulates voltage and frequency as it transfers between grid parallel and grid independent operation. DER converters implement islanding detection algorithms to detect loss of grid power and prevent the DER from continuing to energize the grid. The capability of the converter to vary the frequency, phase and amplitude of its output current allows the implementation of active islanding detection algorithms that are generally superior to the passive methods available for use with synchronous machine based generators.

VII. PROTECTION ASPECTS OF MICROGRID:

A microgrid has to meet two sets of protection criteria: 1) the interconnection requirements of the utility, state or appropriate IEEE standards as they become available and2) the requirement to separate from utility disturbances in a timely fashion so as to preserve the power quality of the microgrid. There may be conflict between these two sets of criteria particularly if it is desired to minimize nuisance separations. Theses conflicts would have to be resolved, negotiated or tolerated

Communication between the DERs in the microgrid may be required for co-ordinated clearing of faults within the microgrid to maintain the function of the microgrid and to minimize seperation from utility. This may require evolving a distribution system version of the pilot wire differential scheme.

Successful operation of an islanded microgrid system will require sufficient fault current sources within the microgrid. Clearing faults with overcurrent devices in low voltage circuits normally require fault currents at least 3 times the maximum load current. This means that the microgrid must contain a large percentage of synchronous generators or inverters with fault current delivery capability.

The most salient need expressed by the relay engineering community is the ability to adequately model the voltage and current dynamics of the microgrid before, during and after a fault condition. The understanding of where the trip/no trip boundaries are in microgrid operation is poorly understood.

VIII. UNLOCKING THE BENEFITS OF MICROGRID:

An integrated program of microgrid pilots, technology platforms and regulatory support would overcome the barriers to microgrids and unlock the benefits.

Phase1: This first phase of pilots should examine the ability of microgrids to reduce energy costs and improve reliability for end-use customers. The technology focus would be a “fast switch” whose function is to seamlessly connect/disconnect the microgrid to the utility grid, possibly implemented using power electronics. The regulatory focus would be to facilitate retail competition while maintaining obligation to serve: and fairly compensate utilities for services provided and investments made.

Phase2: Phase 2 pilots will seek to increase the resilience and security of power delivery system by enabling higher penetration of distributed energy resources. These pilots will examine the microgrid designs that can provide highly reliable services to critical loads during normal grid conditions, and after major outage events. The control focus during Phase2 will begin an outward shift so that the microgrid can become part of a broader utility/community operating strategy. The technology focus will be fast switch and power electronics, black start capability and regulatory focus would be cost recovery of security investments.

Phase3: The microgrids ability to export grid benefits will be explored. The technology focus will be load and generation transfer, advanced control and communications including auto–synchronization with the grid. The regulatory focus would be transparent compensation for environmental, system reliability and permit customers to see the real cost of electricity which include real time, location and environmental attributes.

IX. CONCLUSION:

Overtime microgrids would operate in a coordinated fashion that would support higher level grid reliability and bulk power system security objectives. The modern grid will evolve when the component technologies and operating concepts of the microgrid become ubiquitous. Seen in this light, microgrids become the foundation of a bridging strategy that can take us from today's system to the modern grid. They present us with a means to protect the sanctity of today's distribution system while facilitating the deployment of distributed generation, renewable resources and advanced operating platform.

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