Micro Grid: A Smart Technology

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Abstract
Distributed Generation (DG) is an approach that employs small-scale technologies to produce electricity close to the end users of power. Today’s DG technologies often consist of renewable generators, and offer a number of potential benefits. This paper presents a design of micro grid as part of Smart grid technologies with renewable energy resources like solar, wind and Diesel generator. The design of the microgrid with integration of Renewable energy sources are done in PSCAD/EMTDC. This paper discuss on the advantages and disadvantages future extensions of the microgrid.

Keywords: Microgrid, renewable energy resources (RER), Distribution Generation (DG), Solar, Wind, Diesel-Generator.

INTRODUCTION

India is an energy starved country whose economy is growing at a breakneck speed. The current installed generation capacity is about 162 GW which, with high transmission and distribution losses, translates into a peak time shortage of 12.7% and this is the situation when more than 400 million Indians still don’t have access to electricity. India currently faces a threefold challenge of meeting the current demand, fighting climate change and attaining energy security. This implies that renewables would play a very crucial role in India. India unfortunately has very limited potential geothermal which is still unknown, but luckily India gets good sun fall almost all through the year wind, bio-mass and alternating source with maximum efficiency like diesel generator [1, 2].

A smart grid is a digital upgrade of power system that is capable of assessing its health in real-time, predicting its behavior, adaptation to new environment, handling distributed resources, stochastic demand and optimal response to the smart appliances. A smart grid also includes diverse and distributed energy sources like wind, biomass, solar PV etc; to improve overall system reliability and availability for the benefit of customers and the environment. Integration of two or more DGs improves reliability of smart grid but poses a variety of issues like dynamic response and advanced protection to take into account the bi directional flow of power.

The interest in Distributed Resources (DR), including both Distributed Generation (DG) and energy storage resources, is increasing due to their technical, economical, reliability and environmental merits. Local aggregation of DR systems and electrical loads results in a Micro-grid. The Micro-grid concept has provided a new paradigm for future distribution power systems [4, 5].

Sustainable energy is derived from natural sources sometimes called green power, because they are considered environmental friendly and socially acceptable, they include solar, wind, biomass and fuel cells. The future electric grid will feature rapid integration of alternative forms for energy generation as a national priority. This will require new optimization for energy resources that are distributed with interconnection standards and operation constraints. The legacy grid was designed to handle this change. The stability, reliability, and cost implications of renewable energy resources [2, 3].

The design and development of the smart requires the smart grid requires the modeling renewable energy sources and technologies such as solar, wind, biomass and diesel generator. As part of the integration of the smart technologies in the smart infrastructure system microgrid plays vital role in improvement of efficiency and reliability and the development of state-of- the art and variability.
The challenges of smartgrid technologies include conversion, storage, two way communications, optimal sizing, reliability, self-healing, security and economic benefits. The present paper explains the design considerations of the microgrid, energy conversion and storage models with the PSCAD/EMTDC model with the integration of the Solar, Wind and Diesel generator system.

**Characteristics, advantages and Disadvantages of Microgrid**

The flexibility of micro-grids comprises important benefits, but their efficient implementation poses very challenging problems, as listed next [3]:

- The benefits Micro-grids provide to power system operation and planning need to be quantified and incorporated into an appropriate commercial and regulatory framework, so that a level playing field for all energy technologies can be established. In order to achieve the full benefits from the operation of Micro-grids, it is important that the integration of the distributed resources into the LV grids, and their relation with the Medium Voltage (MV) network upstream, will contribute to optimize the general operation of the system.

- The coordinated control of a large number of distributed sources with probably conflicting requirements and limited communication imposes the adoption of mostly distributed intelligence techniques.

- The design of Micro-source Controllers enhanced with advanced frequency and voltage control capabilities and possessing ride-through capabilities is essential for the stable operation of Micro-grids, especially in islanded mode of operation.

- The design of smart Storage and Load Controllers able to face the stringent requirements posed by the islanded operation and especially during transition from interconnected to islanded mode is also crucial.

Renewable energy options are meant to provide the micro grid with [7]:

- Remote utilization and storage of the renewable energy resources output
- Facilitating give-and-take of the energy from the system
- Redistributing/reallocating of unused power from grid-connected renewable energy sources

- Facilitating storage off grid-generated and RER -generated by back up storage technologies at customer end.

**Renewable Energy sources for Microgrid Technology**

**A. Solar Power Technology**

Solar power in India has huge potential and it is environment friendly as it has zero emissions while generating and is obviously the most secure. Solar power technology enhances PV output by concentrating a large area into a small beam using lenses, mirrors, and tracking systems. There are several PV simulation programs which allow for series analysis for time such as PV design [6]. Cost implication even though the cost of the plant is more manufacturers continue to reduce the cost of installation as new technology is developed for manufacturing materials. Many models exit for the calculation of the power output of a PV cell or bank. Due to varying efficiencies and numerous technologies presently available, power output is effected by environmental conditions and module specifications. The I-V characteristics model of a single cell commonly used for PV technologies shown in figure [1].

![Mathematical model of a PV cell](image)

**Modeling of PV system:**

\[
\text{(1)} \quad \text{(2)} \quad \text{(3)}
\]

Where for an array of \( N_s \times N_{sh} \) solar cells:

\[
\text{(4)} \quad \text{(5)}
\]
Where \( k \) = Boltzmann constant, \( T \) = p-n junction temperature (K), and \( \gamma \) = temperature dependency exponent.

### B. Wind Turbine Systems:

A wind energy conversion system is a complex system in which knowledge from a wide array of fields comprising of aerodynamics, mechanical, civil and electrical engineering come together. The principle components of a modern wind turbine are the tower, the rotor and the nacelle, which accommodates the transmission mechanisms and the generator. Wind/Diesel combinations are, in principal, built up in the same way as are PV/Diesel systems. From a perspective of financial competitiveness, they can be applied in regions where average wind speed is around 3.5 m/s already. If wind speed is sufficient, the wind turbine is in charge of the provision of energy. During short periods of time with low winds, the battery maintains a stable system, being replaced by the diesel generating set when low winds occur over longer periods of time [9, 10].

The power generated by the wind turbine is as follows:

\[
W = \frac{1}{2} \rho RV^3 Cp
\]

Where
- \( \rho \) is the air density (kg/m\(^3\))
- \( R \) is the radius of the turbine
- \( Cp \) is the turbine power coefficient power conversion efficiency of a wind turbine.
- \( V \) is the Wind speed (m/s)
- Total electrical power output is given by

\[
P_t = \eta_m \eta_g W
\]

Where \( \eta_m \) and \( \eta_g \) are the efficiency of motor and generator

### C. Diesel – Generator:

The Diesel generator system consists of two machines: (i) a diesel engine and (ii) a synchronous generator.

#### i). Diesel Engine:

Diesel engines are ubiquitous in society precisely because they are the most efficient and cost-effective prime mover available. This efficiency is primarily due to the high compression ratio that is used to create heat and cause spontaneous ignition of diesel fuel. Because they must be built to withstand the very high internal forces of high compression, diesel engines cost more than other engines. Greater fuel efficiency, reliability, and longevity justify the extra cost. There is a correlation between the amount of fuel burned per unit of work and the exhaust emissions an engine generated. The diesel engine is inherently more fuel efficient than gasoline engines. Therefore, certain exhaust emissions, including those that are routinely tested for in emissions, tested modeled on regulated emissions are lower for diesel engines than for a gasoline engine of comparable age, condition and capability. These regulated emissions include total hydrocarbon (THC), carbon monoxide (CO) and nitrogen oxide (NO\(_x\))[12,13]

#### ii). Point of common coupling:

The PCC module, the node where all power sources and power sinks are connected, must be included in every simulated case (i.e. two case studies). Let us consider some examples. The diesel generator always generates the real power. Therefore, its real power is always positive, or we say that it follows the assumed current sign convention. On the contrary, the diesel generator may generate or absorb the reactive power; the diesel reactive power may be positive or negative, depending on the load demand. The wind turbine generator during the motoring period absorbs real power, meaning that it draws the current from the PCC junction. The direction in which this current flows is the same as the direction assumed. Therefore, the calculated (absorbed) real power is positive. It requires the change of sign to follow the general convention. For the same reason, we must change the sign of the real power calculated when the wind turbine is generating. According to the circuit diagrams in Figure 3, we define the following currents and given in equations (10) & (11):

\[
i_{qpcf1} = i_{qsd} - i_q - i_{qv}
\]

\[
i_{dpfc1} = i_{dsd} - i_d - i_{dv}
\]

Using the same circuit diagram, we write the following equations (12) & (13) defining q-axis and d-axis components \( v_{qd} \) and \( v_{dv} \) of the line voltage \( V_l \):
\[
v_{qs1} = \frac{1}{C_{pf1}} \int (i_{qPFC1} - \omega C_{pf1} v_{ds1})dt, \quad (12)
\]

I. Simulation and Results
The integration of the solar, wind and diesel generator shows the output for the system of the solar PV cell model with the input source current \( I = 100 \text{A} \), series resistance with \( 1 \Omega \), shunt resistance of \( 1 \Omega \), diesel generator as squirrel cage induction machine with rating of \( 230 \text{V} \) and \( 200 \text{A} \) and wind turbine rating as \( 2 \text{MVA} \) with generator rating as \( 230 \text{V} \) with \( 10 \text{A} \) are when connected to the common grid with distributed load of four loads with capacity of \( 1 \text{kw} \) gives the simulation of PSCAD/EMTDC model results at the grid as shown in the figure.4

\[
v_{ds1} = \frac{1}{C_{pf1}} \int (i_{dPFC1} + \omega C_{pf1} v_{qs1})dt
\]

(13)

Where \( C_{pf1} \) is the PFC capacitor

Fig. 3 PCC module circuit diagram: (a) q-axis and (b) d-axis \( V_s \) is calculated according to the equation

\[
V_s = \sqrt{v_{qs1}^2 + v_{ds1}^2}
\]

(14)
Conclusion

Microgrid provides the on-site production of the power without transmission and distribution losses of electricity. Integration of the renewable energy sources will give much effective and more reliable, efficient power supply to consumers. The future extension of the paper can explain integration other renewable sources like Bio-mass and fuel cell models in PSCAD/EMTDC of the microgrid.

References