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REDUCTION IN POWER FLUCTUATIONS OF MICROGRID USING SUPERCAPACITOR

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Abstract: Nowadays renewable energy power generation importance for various applications has been increasing because of the growing power demand and increasing concern about the decreasing level of fossil fuels. Microgrid provides economically attractive electricity supply to customers, which are installable in small localities or on the same building with less impact on the environment. But the issue of power fluctuations arises because of the dependency on the renewable sources. So for such situations an aggregated model has been proposed for integrated renewable sources such as wind and solar power with reduction in power fluctuations using Supercapacitor. The power produced from these renewable sources will be given to the ac or to dc consumers through Supercapacitor and battery energy storage system. Supercapacitor and BESS are connected in the system for reducing power fluctuations and for maintaining the power balance. Thus, in this paper, wind and solar power integration for the microgrid is given with Supercapacitor and battery energy storage for the low output power fluctuations and the storage of the surplus energy for the future use, respectively.

Keywords: Micro Grid, Distributed Energy Resources, Supercapacitor, Battery Energy Storage System.

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INTRODUCTION

With the continuous increase in the demand of electricity and environmental impacts due to large production of electricity using fossil fuels, there is an urgent need of using renewable energy to curb the growing demand. An electrical system that including multiple loads and distributed energy resources that can be operated in parallel with in the border utility grid or as an electrical island is known as micro grid. Distributed power generation allows collection of energy from many sources and has lower environmental impacts and improved power supply. It reduces the amount of energy lost in electricity transmission because it is generated very near or even in the same building. With the increasing demand for improved reliability and energy efficiency across all commercial buildings, a tremendous opportunity exists to capitalize on the benefits of DC micro grids [1], [2].

II. OVERVIEW OF THE PROPOSED SYSTEM

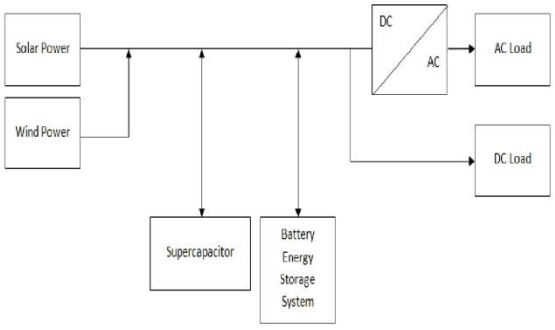

Figure 1: The proposed system

The schematic of the proposed system is shown in the figure 1 which consists of renewable sources, energy storage and super capacitor. Solar energy produces power from PV panels. Through wind energy conversions systems, wind power can be produced in ac and it is converted into dc through ac –dc converter. The power from solar and wind is then combined and given to the desired load by going through Supercapacitor and battery energy storage system. Here Supercapacitor is used for compensating fast fluctuations of power and so provides cache control and battery energy storage system is used for maintaining the supply and demand balance. The proposed system may be installed on the rooftop of commercial or residential building.

Microgrid

The basic definition for Microgrid can be state as a small-scale grid that is designed to provide power for local communities. The main components of a microgrid are Distributed generation sources such as photovoltaic panels, small wind turbines, fuel cells, diesel and gas micro-turbines etc; Distributed energy storage devices such as batteries, super capacitors, flywheels etc.; Critical and non-critical loads; Energy storage devices are employed to compensate for the power shortage or surplus within the microgrid.

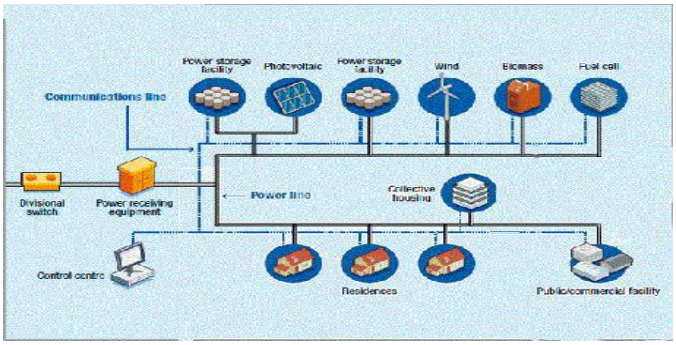

Figure 2: Microgrid [4]

Small scale distributed generation is interconnected to the medium or low voltage distribution systems such as residential building, commercial building, is a market or even a village. In the proposed system, the solar and wind energy is used as the distributed generation system. The integrated power is smoothed with Supercapacitor and the energy is stored in the battery energy storage system which is available for DC and AC customers.

Solar System

Solar power generation involves the generation of electricity from solar energy with the help of photovoltaic panels. PV generation is now more preferred worldwide as Distributed Energy Resources (DERs). The major advantages of a PV system are:

(a) The sustainable nature of solar energy

(b) Positive environmental impact

(c) Longer life time and noiseless operation.

The most commonly used model for a PV cell is the one-diode equivalent circuit as shown in Fig. 3. Since the shunt resistance *R*sh is large, it can be neglected.

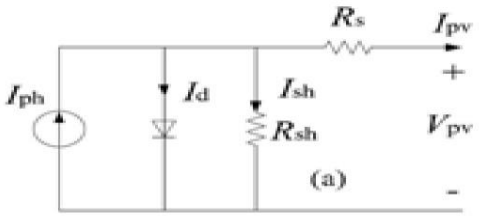

Figure 3. Equivalent circuit for PV cell.

This simplified equivalent circuit model is represented by the following expressions:

$$I_{pv} = I_{ph} - I_d$$

$$I_d = I_0 \left[\exp\left((V_{pv} - R_s I) / V_t \right) - 1 \right]$$

$$I_{ph} = G / G_{ref} \left[I_{ph,ref} + \lambda_I \left(T_c - T_{c,ref} \right) \right]$$

Where I_{ph} is the light current, I_{pv} is the load current and I_0 is the saturation current. The V_{pv} is the output voltage, Rs is the series resistance, the V_t is the thermal voltage, G is the irradiation, Tc is the cell temperature and λ_I is the temperature coefficient. The main PV parameters are V_{mp}, I_{mp}, V_{oc}, I_{sc}, P_{max}.

Wind Energy System

In wind energy conversion systems (WECSs), it includes wind turbine technology, power electronics technology, and system control technology. The wind turbines can also be classified as fixed-speed wind turbines and variable-speed wind turbines based on whether the operation speed is controllable. In the proposed system, fixed speed induction generator wind turbine is used.

Fig. 4 shows the general block diagram of its construction.

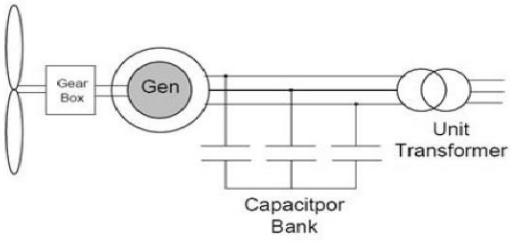

Figure 4: Wind Turbine

Conventional power generation uses synchronous machines; modern wind power systems use induction machines extensively in wind turbine applications. Generally, induction machines are simple, reliable, inexpensive and well developed. They are capable of absorbing rotor speed fluctuations and drive train transients. Fixed-speed induction generators, the stator are connected to the grid via a transformer and the rotor is connected to the wind turbine through a gearbox. The rotor speed is considered to be fixed.

Supercapacitor

Supercapacitor can also be known as ultracapacitor. Supercapacitor uses as a smoothing control unit in the proposed system to reduce the power fluctuations from the integrated power from wind and solar energy. Supercapacitor has the high-power density, high charge / discharge efficiency and long cycle life.

The basic design of a Supercapacitor includes two electrodes/ current collectors, electrolyte and a separator is shown in figure 5[8].

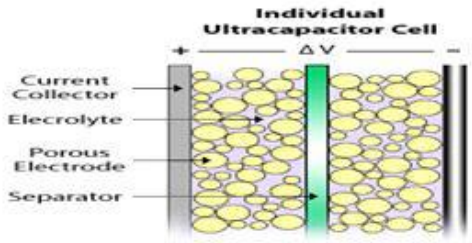

Fig. 5 Individual Ultracapacitor Cell

Capacitor stores energy in the electric field. In a simple conventional parallel plate capacitor, the charge is given by q = CV, where q is charge in Coulombs, C is the capacitance in Farad and V is the voltage across the parallel plates in Volts. Also the capacitance

$$C = \in_0 \in_r \frac{A}{D}$$

Where 'A' is the area of the parallel plates in (meter)^3 , εr is the dielectric constant and ε0 is the permittivity of free space and 'D' is the distance between the parallel plates in meter. The stored energy E in the electric field of a capacitor is given by equation.

$$E = \frac{1}{2} C V^2$$

SCs have an extremely fast discharge and charging response. The storage of SC's capacity is subject to the following constraints:

$Esc\ \min \leq Esc\ (t) \leq Esc\ \max;$

Where *Esc* max and *Esc* min are the maximum and minimum allowable storage capacities of SC. SCs have high reliability, require no periodic maintenance, and have an expected life of 10 years.

Battery energy storage system

The battery energy storage system is used to store the energy from the distributed generation system so that it can be available for real time and future use. It also caters the need of supply and demand balance. The most commonly used batteries are Lead acid batteries. Lead-acid battery storage has advantages like low-cost, good technique and higher energy capacity (MW level), etc.

III. OPERATIONAL OVERVIEW

In the proposed system, the wind and solar energy will be used as distributed generation sources for the Microgrid. The power generated from this should smooth using the smoothing control unit which contains Supercapacitor for reducing the power fluctuations. This smoothed power should be given to the Battery energy storage system. From the battery energy storage system, the power will be making available to the DC and AC consumers for use. In this way, it will increase the efficiency of the system with reduction in the various losses.

IV. RESULT AND WAVEFORMS

The solar power generated with fluctuations is show in figure 6. The wind power generated with power fluctuations is shown in figure 7. The output of the system with and without using supercapacitor is shown in figure 8.

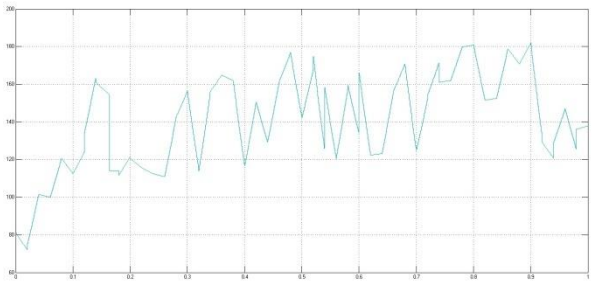

Figure 6: Solar power waveform

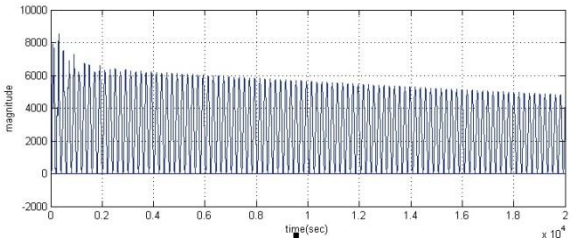

Figure 7: Wind Power Waveform

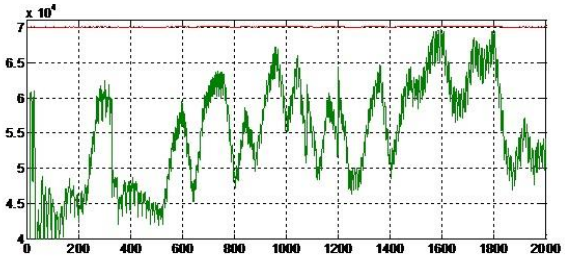

Figure 8: Output of the system with and without Supercapacitor

V. CONCLUSION

This paper gives microgrid which integrates distributed energy generation and energy storage system for meeting the power demand and increasing the system reliability, stability, and efficiency of the system. The combination of wind and solar energy resources on a rooftop were used as Microgrid. But the issue of power fluctuations in PV and wind power generation arises. Thus to overcome this, a method of smoothing power fluctuations using Super capacitor have been proposed. Battery is also integrated in the system so that it can store energy and gives continuous supply to the load. A smoothing control method using Supercapacitor for reducing wind/PV hybrid output power fluctuations and regulating battery under the typical conditions is proposed.

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