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Design of Power Management and Control of a Hybrid Energy System Microgrid

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ABSTRACT

Due to ever increasing energy consumption, rising public awareness of environmental protection, and steady progress in power deregulation, alternative (i.e., renewable and fuel cell based) distributed generation (DG) systems have attracted increased interest. Wind and photovoltaic (PV) power generation are two of the most promising renewable energy technologies. Fuel cell (FC) systems also show great potential in DG applications of the future due to their fast technology development and many merits they have, such as high efficiency, zero or low emission (of pollutant gases) and flexible modular structure. The modeling and control of a hybrid wind/PV/FC based DG system is addressed in this dissertation. Different energy sources in the system are connected to a common dc link bus. Dynamic models for the main system components, namely, wind energy conversion system (WECS), PV energy conversion system (PVECS), fuel cell, power electronic interfacing circuits, battery are developed. The type of fuel cell that have been modeled in this dissertation: proton exchange membrane fuel cell (PEMFC). Power control/load mitigation control of a stand-alone FC system, the maximum power point tracking (MPPT) control for PVECS and wind system SOC of battery addressed in the dissertation. Based on the dynamic component models, a simulation model for the proposed hybrid energy system has been developed using MATLAB/Simulink. The overall power management strategy for coordinating the power flows among the different energy sources is presented in the dissertation. Simulation studies have been carried out to verify the system performance under different scenarios using conventional and fuzzy logic control. The results show that the overall power management strategy is effective and the power flows among the different energy sources and the load demand is balanced successfully.

Keywords: Maximum power point tracking (MPPT),state of charge (SoC), Energy Management, Hybrid energy system (HES).

I. INTRODUCTION

The global warming caused by the abundance of CO2 in the atmosphere and the limitations of global resources of fossil and nuclear fuel has necessitated an urgent search for alternative sources of energy to meet the future demand. It is also important to find alternative energy sources to minimize the negative environmental impact and to cover the continuously increasing demand of power supply. Figure 1 shows the projected availability of fossil and nuclear fuels.

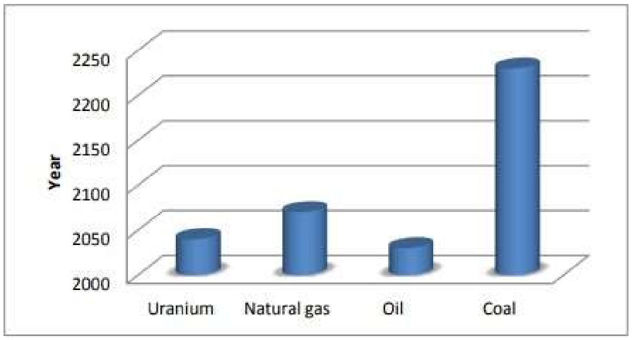

Fig. 1: Projected availability of fossil and nuclear fuels (based on today's rate consumption)

The world energy consumption is expected to grow about 57% in the next two decades. Figure 1.2 shows the strong growth of the global energy demand in the past three decades and its projection over the next two decades. The world energy consumption by fuel type is also shown in the figure. It is clear that a large part of the total energy is provided by fossil fuels (about 86%). The future of the global economy growth is highly dependent on whether the everincreasing energy demand can be met. Fossil fuels are not evenly distributed around the world, and regional or global conflicts may arise from energy crisis if our economy is still heavily dependent on them. Moreover, during the process of generating and using electrical energy with today's conventional technologies, the global environment has already been significantly affected and the environment of some regions has been damaged severely. Therefore, it is a big challenge for the whole world to figure out how to generate the needed amount of energy and the types of energy sources. The world electric energy consumption is expected to increase by more than 50% by 2025 shown in Figure 2. Moreover, the electricity demand from emerging economic regions such as China and India is increasing even faster.

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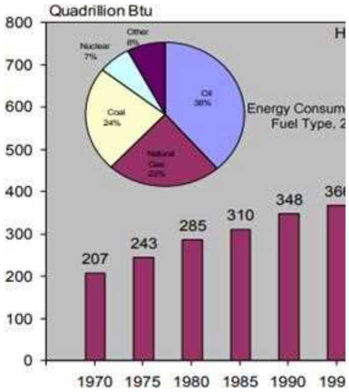


Fig. 2: World Energy Consumption 1970-2025

To meet the future global electricity demand, an extensive expansion of installed generating capacity is necessary. Worldwide installed electricity generating capacity is expected to increase from 3,626 GW (gigawatts) in 2003 to 5,495 GW in 2025 at a 2.2-percent average annual growth rate. Electricity can be generated in many waysfrom various energy sources. Electric power can be generated by conventional thermal power plants (using fossil fuels, or nuclearenergy), hydropower stations, and other alternative power generating units (such as wind turbine generators, photovoltaic arrays, fuel cells, biomass power plants, geothermal power stations, etc.). Fossil fuels (including coal, oil and natural gas) and nuclear energy are not renewable, and their resources are limited. On the other hand, renewable energy resources (wind and solar energy for example) can self-renew and sustain for future use. There is a broad range of energy sources that can be classified as alternative energy such as solar, wind, hydrogen (fuel cell), biomass, and geothermal energy.

Although there are many types of alternative/renewable resources, the alternative sources in this dissertation are confined towind, PV and fuel cells for the research on the proposed hybrid alternative energy systems. The main focus is given to modeling;validation and control for fuel cells, and fuel cell based stand-alone systems. The ultimate goal of this dissertation is to model a multi-source alternative DG system consisting of wind turbine(s), PV arrays, fuel cells and battery system and to manage the power flows among the different energy resources in the system.

Hybrid energy systems:

Photovoltaic power, fuel cell and micro turbine generator to generate power inherent nature of the solar energy and the wind energy, the electric power complementary. The transporting fuel and integrating generating technologies into populated areas far exceeded the cost of developing T&D facilities and tariffs. Central plants are usually designed to take advantage of available economies of scale in a site-specific manner, and are built as "oneoff," custom projects. These economies of scale began to fail in the late 1960s and, by the start of the 21st century, Central Plants could arguably no longer deliver competitively cheap and reliable electricity to more remote customers through the grid, because the plants had come to cost less than the grid and had become so reliable that nearly all power failures originated in the grid. Thus, the grid had become the main driver of remote customers' power costs and power quality problems, which became more acute as digital equipment required extremely reliable elect ricity. Efficiency gains no longer come from increasing generating capacity, but from smaller units located closer to sites of demand.

DER Technologies:

Distributed energy resource systems are smallscale power generation or storage technologies (typically in the range of 1 kW to 10,000 kW) used to provide an alternative to or an enhancement of the traditional electric power system. DER systems typically are characterized by high initial capital costs per kilowatt. DER systems also serve as storage device and are often called

Distributed energy storage systems (DESS). DER systems may include the following devices/technologies:

- Solar Photovoltaic (PV) systems[4]
- Wind power systems
- Fuel cells
- Combined heat power (CHP), also known as cogeneration or regeneration
- Micro turbines

Hybrid energy systems are inter-connected from wind power, to local load and connecting to grid/micro grids. Because of the generations of the PV array and the wind turbine are hybrid PV/wind power system has higher reliability to deliver continuous power than individual source.

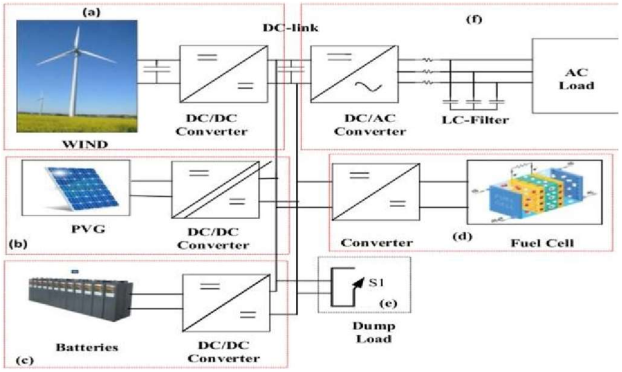
Distribution energy resources:

Historically, central plants have been an integral part of the PV arrays or wind turbines and to deliver the stable power to the load, a electric grid, in which large generating facilities are specifically located substantial battery bank is needed. However, the usage of battery is not an either close to resources or otherwise located far from populated load environmental friendly and there are some

Fig. 3 : Structure of the renewable hybrid energy system

Energy Management Strategy (EMS):

disadvantages like, heavy centers. These, in turn, supply the traditional transmission and weights, bulky size, high costs, limited life cycles, and chemical pollution. distribution (T&D) grid that distributes bulk power to load centers and Therefore one of the ways to utilize the electric energy produced by the PV from there to consumers. These were developed when the costs of array and the wind turbine systems is by directly connecting them to grid.



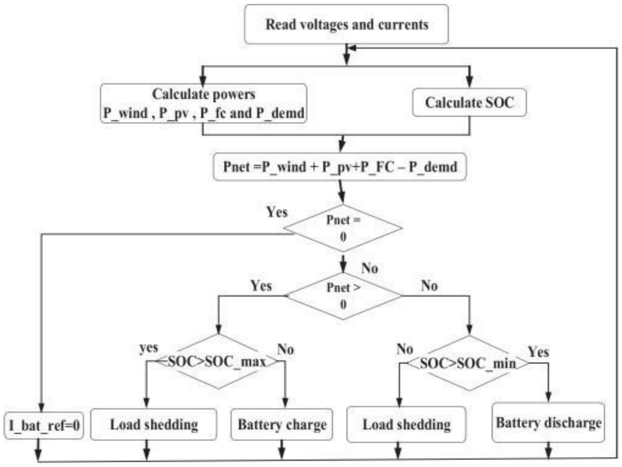


Fig : 5 Hybrid system power management algorithm flowchart

To manage the electrical energy generated by the hybrid system, a developed supervisor was devoted to the optimization of both the energy produced via renewable sources and that of the battery. If the renewable sources do not give enough power and the capacity of the battery is sufficient (SOC > SOCmin), the battery will then supply the missing power (discharge mode, Fig. 10), up to a precisely defined limit, otherwise load shedding is essential to protect the battery. However, if the hybrid power exceeds the load demand, the excess power will be stored in the battery, but if it reaches its maximum (SOCmax), the surplus will be dissipated in a load shedding (here is a resistance). So, the battery is not the main supplier, its charge/discharge rate is reduced thereby extending the battery lifetime. According to current control for the various systems' converters and on the estimated battery state of charge, the supervision algorithm implemented can be represented by the following flowchart:

Energy Storage System Control:

$$SOC_{min} \leq SOC \leq SOC_{max}$$

The DC-link voltage is controlled in Energy Storage System (ESS) through a FOPID control strategy as shown in Fig. 4 below.

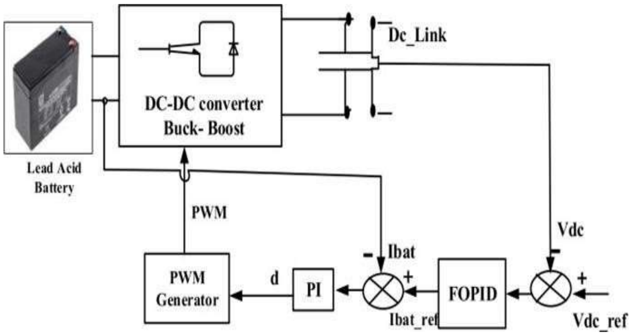


Fig 4: Battery storage control subsystem

Load side control:

The storage system includes a lead-acid battery, and DC-DC in the load or sources. This control is based on Fractional Order PID controller as shown in the fig. 4. The second task is to ensure a power balance between sources and load via charging and discharging the battery by monitoring its State of Charge SOC, which can be presented as follows:

$$SOC = 100\left(1 + \frac{\int i_{bat} dt}{Q}\right)$$

Where Ibat is the battery charging current and Q is the battery capacity. The battery charge - discharge depends on the available power, the demand and the battery SOC. The energy constraints of the battery are determined based on the SOC limits.

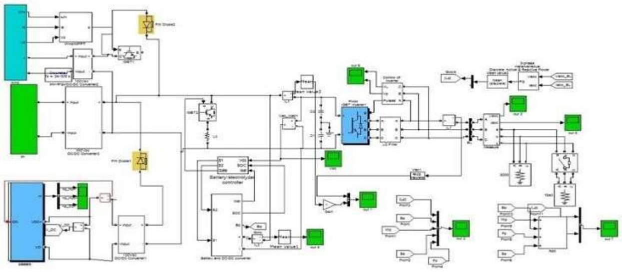
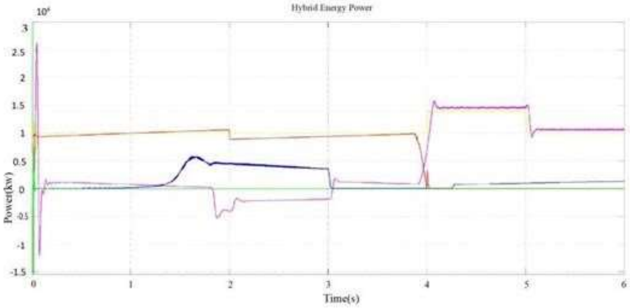


Fig:6 Overall Simulation Diagram of a Hybrid System

Outputs:

(a) Individual Hybrid Energy System Powers

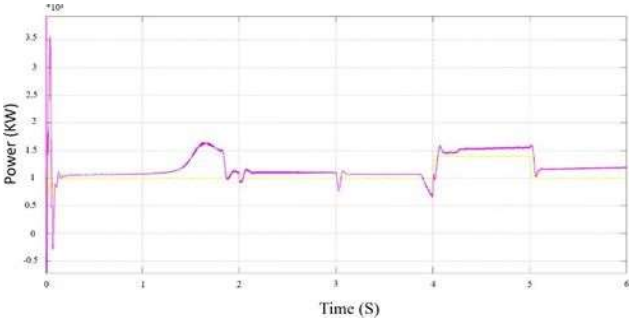


The main task of the three-phase load-side inverter is supplying the load under stable voltage and frequency . As it is known in the distribution system, electrical equipment are mostly single phase, so the current value is not the same in different phases due to unbalanced loads. This leads to unbalanced voltage in different phases, thus, a load voltage control is much needed. To achieve this, a voltage vector adjustment is used. Hence the error between the RMS value of the phase voltages at the point of common coupling and the reference voltage is fed to the PI controller, then the output is multiplied by a unit sine wave generator to get the reference phase voltage (Va_ref, Vb_ref, Vc_ref), which allows to generate PWM pulses for the inverter.

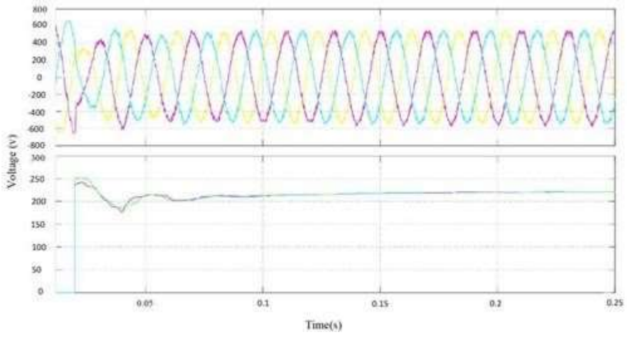
Simulation Results and Discussion:

The following fig. 6 shows the implementation of hybrid energy buck-boost bidirectional converter. The first task of this system is to system and inverter control strategy with conventional PI controller in maintain a DC Link voltage at the desired value whatever the variation MATLAB/Simulink software.

(b)Sum of Hybrid Energy System Powers



(c) Inverter Voltage and DC Link Voltage



II. METHODS AND MATERIAL

Arduino

III. CONCLUSION

In this project it is devoted to the realization of power/energy management of the renewable hybrid system taking into account: a wind turbine, photovoltaic, fuel cell/battery systems and a variable Load. The power electronic converter i.e, inverter control of the system optimizing the control and energy management techniques of the various sources was proposed The AC output voltage regulation was achieved using a Proportional Integral (PI) controller to supply a resistive load with constant amplitude and frequency. Moreover, Fuzzy logic control was implemented for output regulation which archives better performance than PI controller and was very promising for potential applications in hybrid renewable energy management systems.

Future scope:

The project can be further extended with the implementation of the other MPPT control techniques for PV and wind systems. The Power management strategy for a hybrid system based on the battery state of charge and output voltage control can be obtained with other optimization/soft computing techniques.

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