Smart Grid Hybrid Generation System

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ABSTRACT: This report presents a survey work on Hybrid Generation System (two forms of renewable energy—wind and solar) and on the role of smart grids in addressing the problems associated with integration of renewable resources. One of the most challenging aspects of integrating renewable generation resources (renewable) from an operations standpoint, is dealing with their inherit intermittent generation profile. This includes both the non-dispatchable production, as well as the quick generation ramping rates. Wind parks can ramp from zero megawatts (0MW) to full capacity in a matter of hours. Solar photovoltaic (PV) plants can ramp from full capacity to 0MW and back to full capacity in a matter of minutes when a cloud passes overhead[3]. This can be a huge operational challenge, when people expect a constant supply of electricity to their home, managing a high amount of supply that comes from a resource that can drop to 0MW in a matter of minutes can be challenging to say the least. With these daunting challenges in play, it can be overwhelming to think about how to integrate renewable resources onto the grid. However, there are solutions that can be implemented now as well as longer-term solutions that will allow us to accomplish the task of integrating renewable with conventional generation resources. Finally, a solution is to take advantage of the up and coming smart grid to balance load pockets with intermittent renewable generation. The use of more efficient control strategies would not only increase the performance of these systems, but would increase the number of operational hours of solar and wind plants and thus reduce the cost per kilowatt-hour (KWh) produced [1].

1. INTRODUCTION:

The world is getting increasingly convinced of the harmful impacts of global warming. Diminishing of polar ice, erratic weather, devastating hurricanes, warm winters are some of the indicators. Global warming has been linked to energy use practices around the world and an international effort is underway to shift energy supply to non-polluting and renewable sources of energy. The problems of the developing countries are some-what different.

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The economies like India, China, Brazil etc., in their evolution, have reached a point of steep growth in economic and industrial development and the per capita energy consumption is likely to go up significantly.

If these economies do not embark on non-polluting energy strategies, it would not only be difficult to sustain such a course due to the finite fossil fuel reserves, but also earth would be pushed further towards a crisis resulting from global warming. While there are some people, who advocate nuclear power as a solution, this option has its own perils, which can be more severe than global warming. In this scenario, developing countries are faced with a dilemma and have to necessarily look for energy options, that on the one hand, allow them to continue with growth, and on the other hand, to limit or eliminate the causes of global warming. For developing countries, search for alternative energy options is driven by concerns of energy security as well as environmental issues. In early seventies, rise in oil prices encouraged the power generation from the wind energy& solar energy. Since then more focus has been given to extraction of electrical energy from wind & Solar energy rather than extracting mechanical energy. Since, they are dilute and variable in nature, many complexity exist in conversion, condition, control, coordination etc. They are utilized as a standalone system to electrify many applications like lighting system, water pumping for irrigation, traffic control, T.V in remote areas etc,. But it is costly, unreliable, and stiff need individual conditioner and controlling units. In this challenging atmosphere Hybrid Energy System (HES) is one of the viable solutions to harvest energy from renewable energy resources. Generally, PV power and wind power are complementary since sunny days are usually calm and strong winds often occur on cloudy days or in nighttime. The hybrid PV-wind power system therefore has higher availability to deliver continuous power and results in a better utilization of power conversion and control equipment than either of the individual sources.

Hybrid System essentially consists of two or more energy sources required to meet the energy demanded by the load & increases the efficiency of the system. One example of a hybrid energy system is a photovoltaic array coupled with a Wind generator. This would create more output from the wind turbine during the winter, whereas during the summer, the solar panels would produce their peak output. Hybrid energy system uses Complementary Nature of these sources. It eliminates the Zero power intervals. All these generating systems have some drawbacks, like Solar panels are too costly and the production cost of power by using them is generally higher than the conventional process, it also is not available in the night or cloudy days. Similarly Wind turbines can't operate in high or low wind speeds. Figure 1 shows a simple diagram of the different components of the hybrid system connected to the grid..

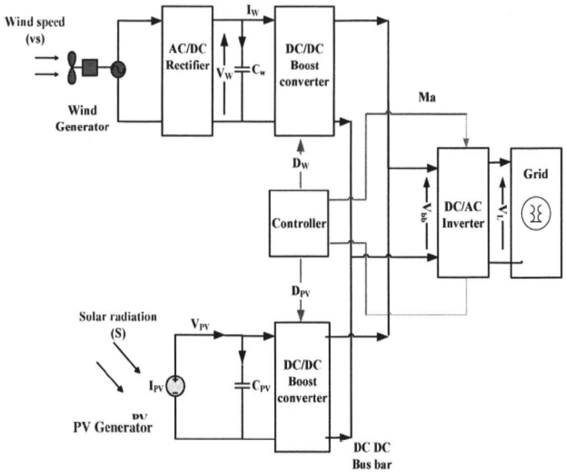

Figure 1 Hybrid Generation System

The power electronic interface consists of; an uncontrolled rectifier, a boost DC/DC converter and the grid inverter that is shared with the PV generator. The DC busbar voltage (Vbb) is adjusted as constant by means of the power angle (0), which is the phase angle between the grid voltage and the voltage on the inverter output. The volt-ampere reactive (VAR) is controlled by a control loop using the amplitude modulation index (Ma) in the PWM process of the inverter. wind speed and a statistic model of the solar radiation are used as the inputs for the wind generator and the PV generator respectively.

The smart grid—an evolution of electricity networks toward greater reliance on communications, computation, and control—promises a solution. For example, if an area experiences a spike in load, a wind resource is producing excess generation, then theoretically that wind supply could be scheduled to directly offset that load. Also, if distributed generation proliferates, then possible the smart grid could balance load pockets with localized renewable generation, and use conventional generation from the grid as a balancing or contingency reserve. Both of these speculations on the future implementation and use of the smart grid, but could prove to be viable solutions.

The application of advanced digital technologies (i.e., microprocessor-based measurement and control, communications, computing, and information systems) are expected to greatly improve the reliability, security, interoperability, and efficiency of the electrical grid, while reducing environmental impacts and promoting economic growth. To realize Smart Grid capabilities, deployments must integrate a vast number of smart devices and systems. The smart grid can be conceptualized as an extensive cyber-physical system that supports and facilitates significantly enhanced controllability and responsiveness of highly distributed resources within electric power systems.

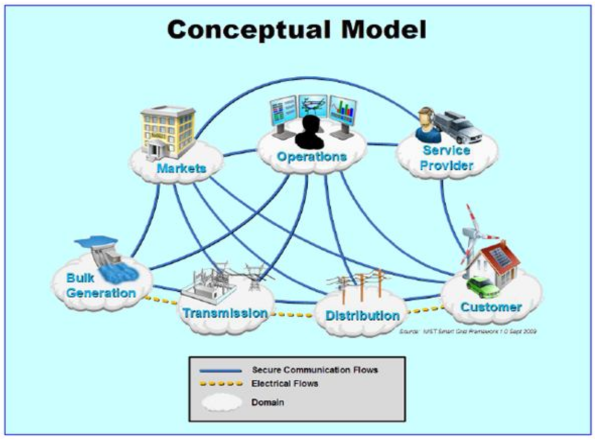

Figure 2 conceptual model of smart grid

Wind Energy

Winds are generated by complex mechanisms involving the rotation of the earth, heat energy from the sun, the cooling effects of the oceans and polar ice caps, temperature gradients between land and sea and the physical effects of mountains and other obstacles. Some of the windiest regions are to be found in the coastal regions of the Americas, Europe, Asia and Australasia. Most mountain regions are also windy, while the interiors of large land masses are generally less so.The total resource is vast; one estimate suggests around a million gigawatts (Cole, 1992) 'for total land coverage'. If only 1% of the area was utilized, and allowance made for the lower load factors of wind plant (15-40%, compared with 75-85% for thermal plant), the wind-power potential would still correspond, roughly, to the total worldwide capacity of all electricity-generating plant.

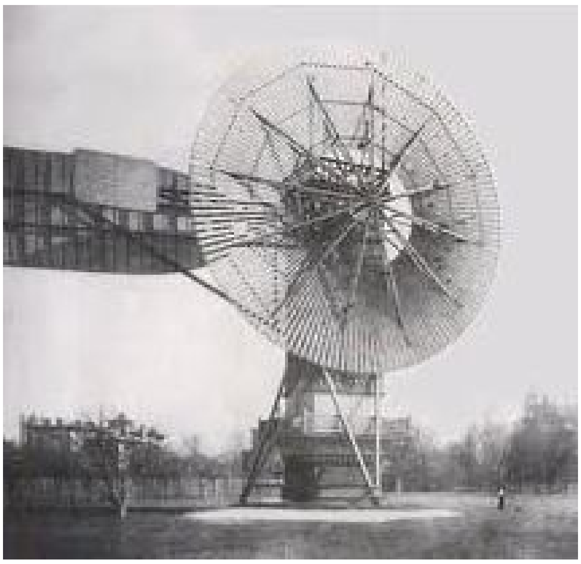

Figure 3 Charles F. Brush's wind turbine (1887, Cleveland, Ohio), the world's first automatically operating wind turbine for electricity generation.

Goals and Approach

Figure 4,5 illustrates two common approaches to variable-speed wind power generation. In each of these, an alternating current–alternating current (AC–AC) power electronics system interfaces with and converts the variable-voltage variable-frequency AC appearing at generator terminals to the constant-voltage constant-frequency AC of the utility system.

To fully realize the potential of variable-speed generation to harvest the energy available over a wide range of wind speeds, all elements of the system must be designed to operate with high efficiency over the entire operating range. Because a typical wind generation system may operate at a fraction of rated power most of the time, attaining high efficiency at light load is critical for reducing the cost of energy (COE) in these systems.

This requirement distinguishes the wind power application from nearly all other applications where efficiency at light load is usually much less important than other considerations, such as the efficiency at full load. Although previously many works have been devoted to optimizing the design of the wind turbine and the machine to meet this requirement, much less work has focused on similar optimization of the power electronics. Furthermore, typical off-the-shelf converters exhibit poor efficiency at light loads.

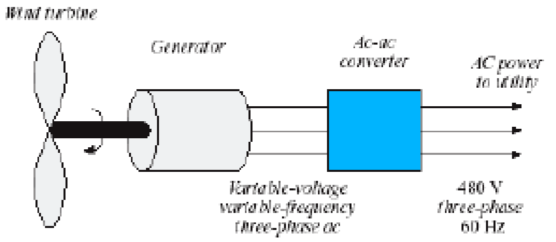

Figure 4

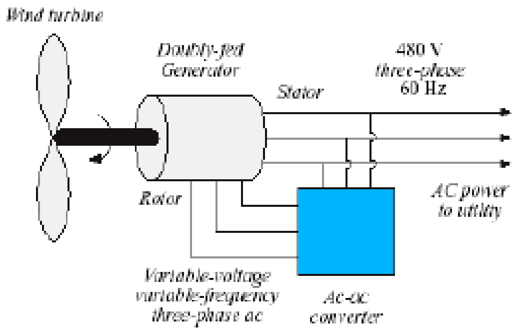

Figure 5

Solar Energy

Renewable energy resources have attracted public, governmental & academic attention due to the global energy crisis. Among the alternative energy sources used for the production of electricity, the wind & the photovoltaic solar energy became more attractive these last year's .For sectors where electricity was not accessible, where the wind is not proportioned to produce required demand, the solar systems were employed more & more. A Photo-Voltaic Generator (PVG) is composed of a certain number of solar cells connected like series & parallel according to the required power. Although their prices decrease, the systems of PVG always require expensive investments. Consequently, it is very significant to extract maximum of energy from PVG.

The PV energy applications can be divided into two categories.

i) Stand-alone system

ii) A grid-connected system

The conventional stand-alone PV systems have the advantages of simple system configuration& control schemes. However, in order to draw maximum power from PV arrays & store excess energy, battery banks are required in these systems & are suitable for low-power applications. For high power systems, they will increase system cost, weight &narrow the application areas. Therefore ,grid-connected systems, which are designed to relieve this short-comings have became the primary researches in PV power application.

The output voltage from PV array is changeable with solar radiation & ambient temperature. So in order to connect the electrical grid, the output voltage from PV array should be fixed& converted to AC voltage which can be done by inverter. The PV converter &PV inverter have the task to guarantee safe & efficient operation, to track the maximum power of the PV solar array& controlling the power which is injected from the inverters to the electrical grid. A important technique for achieving maximum power from PV arrays is called Maximum Power point Tracking(MPPT).The MPPT algorithm(perturbation& observation method, incremental conductance method, fuzzy logic control, neural network algorithm) when applied, an accurate PV model has the ability to increase the efficiency of the system..So by using these algorithms, the optimal operating point is identified& the maximum power from the solar array is estimated.

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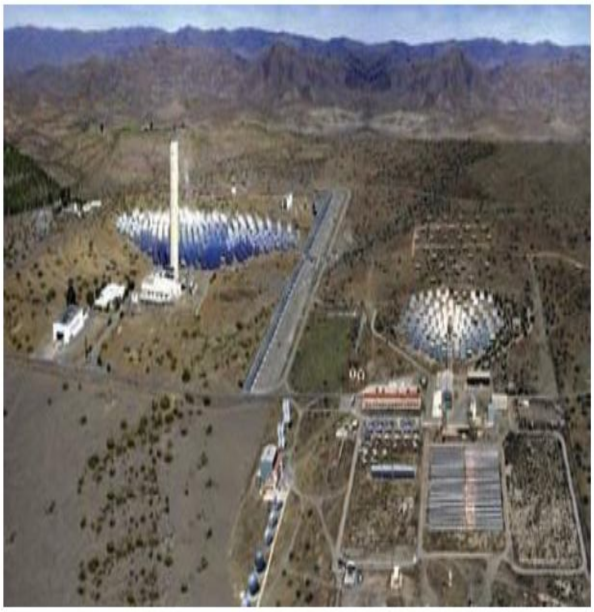

Figure 6 Plataforma Solar de Almeria (PSA)

The control system shown can be implementing several control functions to perform the following tasks.
i) Control the boost converter to fond the maximum power point of the PV output.
ii) Control the inverter for synchronizing the output voltage to the grid voltage with a high power factor
iii) Control the connection of PV system to the grid & load shedding under islanding condition.
The main task of the grid connected PV system control system is to be sure that the signals of the inverter output& grid signals have the same frequency, phase & RMS values. Many control schemes are applied for different inverter configuration, to get better power quality.

For Current-controlled PV inverters in most of the cases we make use of PI controller with grid voltage. PI controllers are designed with the approximation model of the PV system around an operating point. However when the system does function in the neighborhood of another operating point,PI controller will fail to operate. So this solution exhibits two well known drawbacks (due to poor performance of the integral action)
i) Inability of the PI controller to track a sinusoidal reference without steady –state error
ii) Poor disturbance rejection capability.
Then another non-linear control Sliding mode control can be used which is robust in the presence of parameter uncertainties & disturbances. It is able to constrain the system status to follow trajectories which lie on a suitable surface in the sliding surface. The main steps for SMC design can be summarized
i) Selecting switching surface s(x,t)=0 that provides the desired asymptotic behavior in steady state.
ii) Obtaining equivalent control $u_{eq}$by applying Invariance condition. s(x,t)=0&$\dot{s}$(x,t)=0 $\Rightarrow u(t) = u_{eq(t)}$
iii) Finally selecting a non-linear control input to ensure that Lyapunov stability criteria s&$\dot{s}$<0.

A sine reference tracking state feedback current control approach using the Pole Placement technique can also be used as another control scheme. A current controller of the grid connected inverter controls the output current of inverter to be in phase with the grid voltage, which has a sine waveform. The objective is to design an overall system such that the output will track asymptotically a sine reference input, even with the presence of an input disturbance& with plant parameter Variations. If the system is controllable, there exist a state feedback gains, then the system is stable that means the output current of the inverter tracks the sine reference value to be in phase with the grid voltage for high power factor. The system Eigen values can be placed to the desired poles, from which the state feedback gains are determined. Then using dominant pole approach for the pole placement technique, the desired pole locations can be easily obtained.

The fuzzy Logic controller is somewhat easy to implement because it does not need the mathematical model of a system. Since it gives the robust performance, the interest in practical application of fuzzy logic is growing rapidly. It is possible to define the control laws by sentences rather than equations because a fuzzy controller can be build on the basis of empirical rules such as IF condition 1AND condition2 THEN conclusion. The FLC have the advantages of working with imprecise inputs, not needing an accurate mathematical model& handling non-linearities.The proposed FLC consist of 3 stages:-fuzzification,inference& defuzzification.

The state model of PV system mainly nonlinear. To control such a nonlinear system many techniques do exist. i) State space Feedback linearization ii) Input output feedback linearization. The State space Feedback linearization technique is used for controlling the grid connected PV interface Current& for maximum power point tracking. The main advantage is its insensitivity to operating point. A linearization control law is designed, after applying this law to the system, this becomes linear. So a linear control law can be designed with pole-placement for stabilizing the system.

Smart Grids

The rapid deployment of renewable energy technologies and their larger deployment in the near future, raise challenges and opportunities regarding their integration into energy supply systems. Energy systems are needed to meet the demands for a broad range of services (household, commerce, industry, and transportation needs...).The electricity supply system is mainly composed of large power units, mostly fossil fuelled and centrally controlled, with average capacities of hundreds of MW.It can reduce the transmission and distribution losses as well as transmission and distribution costs, Provide customers with continuity and reliability of supply, Stimulate competition in supply, adjusting prices via market forces[2].

Power systems are fundamentally reliant on control, communications, and computation for ensuring stable, reliable, efficient operations. Generators rely on governors and automatic voltage regulators (AVRs) to counter the effects of disturbances that continually buffet power systems, and many would quickly lose synchronism without the damping provided by power system stabilizers (PSSs). Flexible AC transmission system (FACTS) devices, such as static var compensators (SVCs) and high-voltage DC (HVDC) schemes rely on feedback control to enhance system stability. At a higher level, energy management systems (EMSs) use supervisory control and data acquisition (SCADA) to collect data from expansive power systems and sophisticated analysis tools to establish secure, economic operating conditions. Automatic generation control (AGC) is a distributed closed-loop control scheme of continental proportions that optimally reschedules generator power set points to maintain frequency and tie-line flows at their specified values[1].

Smart Grid Uses information technologies to improve how electricity travels from power plants to consumers, Allows consumers to interact with the grid, Integrates new and improved technologies into the operation of the grid
There are Many Definitions –_"A smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. It also incorporates the use of superconductive transmission lines for less power loss, as well as the capability of integrating alternative sources of electricity such as solar and wind."
"An automated, widely distributed energy delivery network characterized by a two-way flow of electricity and information, capable of monitoring and responding to changes in everything from power plants to customer preferences to individual appliances."

The Drivers for Smart Grid are raising costs of capital, raw materials, and labor aging infrastructure and workforce, Calls for energy efficiency, growing demand for energy, and Rapid innovations in Technology .The Integration Issue arises when large numbers of DG units are interconnected to conventional grid, stability is affected. Customer can also inject energy into grid-bidirectional flow of energy- energy meter shall support bidirectional flow of energy recording. Energy recording, tariff and billing – to be reworked. It also needs real time monitoring and Control.

Technologies &Applications

Smart grid concepts encompass a wide range of technologies and applications.

i) **Advanced Metering Infrastructure (AMI)** Provide interface between the utility and its customers: bi-direction control. AMI is not a single technology, but rather an integration of many technologies that provides an intelligent connection between consumers and system operators. AMI gives consumers the information they need to make intelligent decisions, the ability to execute those decisions and a variety of choices leading to substantial benefits they do not currently enjoy. In addition, system operators are able to greatly improve consumer service by refining utility operating and asset management processes based on AMI data..It consist of multiple technologies smart metering, home area networks, integrated communications, data management applications, and standardized software interfaces.

ii) **Distribution management system (DMS)** Distribution management system (DMS) software mathematically models the electric distribution network and predicts the impact of outages, transmission, generation, voltage/frequency variation, and more. It helps reduce capital investment by showing how to better utilize existing assets, by enabling peak shaving via demand response (DR), and by improving network reliability.

iii) **Geographic information system (GIS)** technology is specifically designed for the utility industry to model, design, and manage their critical infrastructure. By integrating utility data and geographical maps, GIS provides a graphical view of the infrastructure that supports cost reduction through simplified planning and analysis and reduced operational response times.

iv) **Outage management systems (OMSs)** speed outage resolution so power is restored more rapidly and outage costs are contained. They eliminate the cost of manual reporting, analyze historical outage data to identify improvements and avoid future outages, and address regulatory and consumer demand for better responsiveness.

v) **Wide-area measurement systems (WAMS)** provide accurate, synchronized measurements from across large-scale power grids.WAMS consist of phasor measurement units (PMUs) that provide precise, time-stamped data, together with phasor data concentrators that aggregate the data and perform event recording Health Monitor: Phasor measurement unit (PMU) Measures the electrical waves and determine the health of the system, Increases the reliability by detecting faults early, allowing for isolation of operative system, and the prevention of power outages

Application Challenges& Issues

A significant challenge associated with smart grids is the integration of renewable generation. Most renewable resources are intermittent and cannot be relied on (in its present form) for secure energy supply.

Another promising focus for the controls community related to the smart grid is power electronics, which is playing an increasingly important role in grid connection of loads and generation. Power electronic interfaces tend to decouple device behavior from grid disturbances. This decoupling can have a detrimental effect on the response of the grid frequency and can accentuate voltage collapse.

Finally, on the architectural front, smart grids will require new distributed control structures to fully exploit the new, and widely distributed, sensors and actuators. Present Infrastructure is inadequate and requires augmentation to support the growth of Smart Grids.

Conclusions

Most national energy policies worldwide aim at ensuring an energy portfolio that supports a cleaner environment and stronger economy and that strengthens national security by providing a stable, diverse, domestic energy supply. Clean energy is a global and urgent imperative. Renewable generation, especially from wind and solar, and smart grid concepts are critical technologies needed to address global warming and related issues. The key challenge is to reduce the cost of renewable energies to affordable levels. Control and related technologies will be essential for solving these complex problems [1].

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