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A Review of Renewable Energy Systems for Industrial Applications

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Abstract: Integrated renewable energy systems have numerous advantages and benefits compared to conventional energy systems, such as decentralized energy production, environmental impact reduction, and better energy security. Renewable energy systems can be classified under various categories: solar, wind, hydroelectric, biomass, geothermal, and ocean. The integration of these renewable energy resources can bring sustainable solutions and multiple products. The case studies signify the potential integration options of renewable energy systems including energy storage. Non-conventional renewable energy sources and systems (RESS) including but not limited to biomass, biogas, geothermal etc are increasingly playing an important role for electric power distribution and storage. The idea is to develop a resilient energy infrastructure minimizing the cost of remote power and support green and sustainable development efforts. Smart Grids use digital technologies and IOT solutions to intelligently react and adapt to changes in the Grid. Siemens Accelerator for Grids portfolio is the key to exploit the data in the grid. This allows operators to make grid operation more flexible, cost-efficient, more reliable, maintainable, safer and therefore, feasible.
Keywords: Integration, resilient, conventional, smart grid.

I. INTRODUCTION

As concern about climate change, rising fossil fuel prices and energy security increase, there is growing interest around the world in renewable energy resources. Since most renewable energy sources are intermittent in nature, it is a challenging task to integrate a significant portion of renewable energy resources into the power grid infrastructure. There are many communication options available for the grid integration of renewable energy resources. These options include a hybrid mix of technologies, such as fiber optics, copper-wire line, power line communications, and a variety of wireless technologies. While renewable energy systems are capable of powering houses and small businesses without any connection to the electricity grid, many people prefer the advantages that grid-connection offers. A Grid –connected systems allows you to power your home or small business with renewable energy during those periods (daily as well as seasonally) when the sun is shining, the water is running, or the wind is blowing. Any excess electricity you produce is fed back into grid supplies your needs, eliminating the expense of electricity storage devices like batteries.
In addition, power providers (i.e., electric utilities) in most states allow net metering, an arrangement where the excess electricity generated by grid-connected renewable energy systems "turns back" your electricity meter as it is fed back into the grid. If you use more electricity than your system feeds into the grid during a given month, you pay your power provider only for the difference between what you used and what you produced. The model for grid with renewable energy sources is presented in Fig. 1.

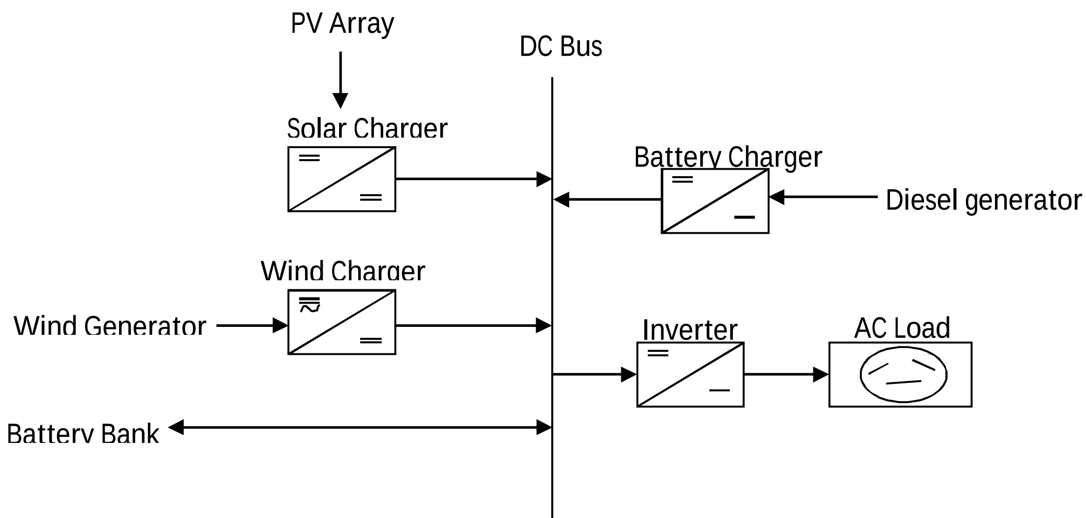

Fig. 1: Model for grid with renewable energy sources

A. Equipments Required for Grid-connected System

Aside from the major small renewable energy system components, you will need to purchase some additional equipment (called ‘‘balance-of-system’’) in order to safely transmit electricity to your loads and comply with your power provider’s grid-connection requirements. You may need the following items:

1) Power conditioning equipment
2) Safety equipment
3) Meters and instrumentation.

Because grid-connection requirements vary, you or your system supplier/installer should contact your power provider to learn about its specific grid-connection requirements before purchasing any part of your renewable energy systems.

In addition, distinct characteristics in electric grid pose new challenges to the communication systems for grid integration of renewable energy resources. In this paper we will review some communication technologies available for grid integration of renewable energy resources.

II. LITERATURE SURVEY

1) Aghaei and Alizadeh (2012) reported that the process have been carried out to one of the most recent challenging issues regarding RERs (i.e. wind power generation, photovoltaic resources, solar systems) is that highly profitable resources are inherently sporadic and cannot be employed as dispatchable resources. Many attempts have been recently done to mitigate the intermittency behavior of RERs. Energy Storage Systems (ESSs) and DRPs are two major applicable solutions presented in other research papers. Authors proposed a novel multi-directional interactive Dynamic Monitoring and Decision-making Systems (DYMONDS) algorithm to execute near-optimal predictive dispatch, instead of commonly used Security-Constrained Economic Dispatch (SCED). Same authors showed, in a case study that the look-ahead dispatch of the proposed method is physically implementable and when used with the elastic demand, wind power generation up to 50% can be accommodated. They showed that the most systematic way to implement the existing infrastructure is to enable current available SCADA with a multi-directional information exchange between the control center and the distributed decision maker. With the use of this information, interactively to manage inter-temporal constraints by distribution decision makers to make their supply and demand functions, and have system operator to clear the supply and the demand functions by running today’s SCED with its special constraints.
2) Saradhi et al. (2014) presented a novel control strategy for achieving maximum benefits from these grid interfacing inverters when installed in 3-phase 4-wire distribution systems. Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. Therefore, the DG systems are required to observe with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network. In this paper the grid-interfacing inverter can effectively be employed to perform following important outcomes:

a) Transfer of active power harvested from the renewable resources (wind, solar, etc.)
b) Load reactive power demand support
c) Current harmonics compensation at PCC and
d) Current unbalance and neutral current compensation in case of 3-phase 4-wire system.

Moreover, with adequate control of grid-interfacing inverter, all the four objectives can be accomplished either individually or simultaneously. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost.

3) Carrasco et al. (2006) suggests that it should be possible to develop the power-electronic interface for the highest projected turbine rating, to optimize the energy conversion and transmission and control reactive power, to reduce harmonic distortion, to attain at a low cost a high efficiency over a wide power range, and to have a high reliability and tolerance to the failure of a sub-system component. In this paper, the common and future trends for renewable energy systems have been reported. As a current energy source, wind energy is the most modern technology due to its installed power and the recent improvements of the power electronics and control. In addition, the applicable regulations favor the increasing number of wind farms due to the attractive economical reliability. Furthermore, the trend of the PV energy leads to examine that it will be an interesting alternative in the near future when the current problems and disadvantages of this technology (high cost and low efficiency) are solved. Eventually, for the energy-storage systems (flywheels, hydrogen, compressed air , supercapacitor , superconducting magnetic, and pumped hydroelectric), the future presents several fronts, and actually, they are in the same development level.

4) Hall and Bain (2008) introduced the principles and the importance of energy storage that are becoming increasingly important as many countries are placing greater significance on electrical production from renewable sources. As the contribution of electricity generated from renewable sources (wind, wave and solar) grows, the intrinsic irregular of supply from such generating technologies can only be convey by a step-change in energy storage. This review focuses on the scientific and engineering requirements to develop these technologies. Furthermore, the continuously developing demands of current applications require the design of versatile energy-storage/power supply system offering wide ranges of power density and energy density. As no single energy-storage technology has this capability, systems will comprise combinations of technologies such as electrochemical supercapacitors, flow batteries, lithium-ion batteries, Superconducting Magnetic Energy Storage (SMES) and kinetic energy storage. The progression of the electrochemical super capacitor is largely dependent on the expansion of optimized electrode materials and electrolytes. Given the suitable research effort, the key scientific advances required in order to successfully develop energy-storage technologies generally represent realistic goals that may be achieved by 2050.
5) Chandra et al.(2011) presented a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wire DG system. The grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid-interfacing inverter with the proposed approach can be utilized to:

a) Inject real power generated from RES to the grid, and/or,
b) Operate as a shunt Active Power Filter (APF).

This approach thus, abolishes the need for additional power conditioning equipment to improve the power quality at PCC. The combination of grid-interfacing inverter and the 3-phase 4-wire linear/non-linear unbalanced load at point of common coupling appears as balanced linear load to the grid. This new control concept is demonstrated with extensive MATLAB/Simulink simulation studies and verified through digital signal processor-based laboratory experimental results.

6) Zhang et al. (2010) proposed a innovative method to control Grid-connected voltage-source converters. The control method is verified by both analytical models and time simulations. In high voltage DC applications, this method can be generally applied. Different from the previous control methods, the proposed method utilizes the internal synchronization mechanism in AC systems, in principle, similar to the operation of a synchronous machine. Pulse Width Modulation (PWM)-based voltage source converter (VSC) techniques have been widely used in grid-connected applications, such as adjustable-speed drives (ASDs) with PWM rectifiers, power quality improvement, wind turbines, etc. Disadvantages of power-angle control are that the control bandwidth is limited by a resonant peak at the grid frequency and the control system does not have the capability to limit the current flowing into the converter. In high-power applications, it is highly important for the control to limit the valve current to prevent the converter from being blocked (tripped) at disturbances. Vector-current control is a current-control-based technology. Thus, it can naturally limit the current flowing into the converter during disturbances. The basic principle of vector-current control is to control the instantaneous active power and reactive power independently through a fast inner current control loop.
7) Yuvaraj et al. (2011) concluded that the FACTS device (STATCOM) -based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The proposed control scheme is simulated using SIMULINK in power system block set. To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind, biomass, hydro, co-generation, etc. The issue of power quality is of great importance to the wind turbine. There has been an extensive growth and quick development in the exploitation of wind energy in recent years. The proposed STATCOM control scheme for grid connected wind energy generation for power quality improvement has following objectives:

a) Unity power factor at the source side.
b) Reactive power support only from STATCOM to wind Generator and Load.
c) Simple PI controller for STATCOM to achieve fast dynamic response.

The integrated wind generation and FACTS device with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC Standard 61400-21.

8) Ito et. al., (2010) described a control technique developed in the Japanese national project "Verification of Grid Stabilization with Large-scale PV Power Generation Systems. A high performance harmonic current reduction control scheme has been presented. Its purpose is to reduce the harmonic current that flows through a PCS by outputting harmonic voltage equal to the one contained in the grid. Extraction algorithm for the harmonic voltages enables the VSI in the PV generation system to output harmonic voltages that are very close to the harmonic voltage of the grid.

There are two control methods for reducing the harmonic currents:

a) Feedback-based current control
b) Disturbance compensation control

In this project, three control methods were developed:

- Generation power control for fault ride through
- Harmonic current reduction control scheme
- Grid voltage stabilization using optimal reactive power control.

III. RESEARCH METHODOLOGY

The purpose of this research is to provide resources to the need of energy in production field and also consume energy in a perfect manner with higher efficiency at low cost.

A. *Wind-Solar Fields*

The complementary nature of wind and solar determines the advantages and potentiality of hybrid power generation systems. Off-grid wind-solar hybrid power generation systems are very important that includes design methods, capacity configuration of different parts, the classification and features of storage energy systems, is analyzed thoroughly. In an ideal system, wind and solar electricity are both injected in a fast reacting grid instantaneously matching supply and demand.

Mikati et al. (2013) analyzed that Each sub-system contains a power demand typical for a household or a small factory or store and receives power from photovoltaic (PV) arrays, a small-scale wind turbine and the electric grid. The coupling of sub-systems reduces the grid usage always if, at any moment, one subsystem is generating excess power while the other has a power deficit. The coupling of subsystems can reduce grid power exchange by more than 10% and increase the renewable power contribution to the demand by almost 7%.

The Solar resource: Solar radiation on earth can be modeled as the sum of a direct and diffuse contribution. The direct radiation (or beam radiation) represents the solar radiation received by a plane without having been scattered by the atmosphere. The influence of the atmospheric conditions is, in the clear sky model, determined by the altitude and the climate type.

The Wind resource: The wind resource on a particular site depends on a mass of aspects, such as: the earth's thermal mass, topography and latitude. An increased elevation above ground generally leads to smoother winds since surface roughness provokes unstable behavior. The wind was considered to consist of an average wind speed profile, with two types of random distortion superposed:

- Turbulence, that disturbs all data points of the day with the same probability.
- Stronger fluctuations that affect only parts of the day.

It is possible to adjust the distortion of the average wind profile to increase or smooth-out uncertainties.

B. *Fossil Fuel*

The world's industrial powers are searching for new avenues of energy production as dependency on fossil fuel declines.

Petroleum Extraction- First, the quality of energy inputs and outputs in petroleum extraction is closely matched relative to coal extraction. The extraction of oil and natural gas uses large amounts of fuels made from oil and gas, and to a lesser degree electricity. Second, the fuel mix of energy inputs has always been dominated by oil products and especially natural gas. As a result of the closer match of quality in energy inputs and outputs, the thermal equivalent EROI for petroleum extraction is moderately larger than the quality-corrected EROI. Khalil et al. (2017) stated ''The Benefits of the Transition from Fossil Fuel to Solar Energy in Libya: A Street Lighting System Case Study''. Libya situates in the high sunny belt and has a long coastal line on the Mediterranean sea, which make it one of the countries that have very high potential for solar energy and wind energy. The electricity consumers in Libya suffer from the unpleasant long hours of load-shedding, which has negative impacts on the life of the people. The cost of the connection to the grid depends on the distance, the power and the voltage level. Four alternatives are to be investigated, two are fossil fueled and the other two are renewable:

- Fossil fuel grid connected HPS lamp lighting system
- Fossil fuel grid connected LED lighting system
- Stand-alone solar powered LED street lighting system
- Grid connected solar powered LED lighting system.

C. Photovoltaic Systems

In China, floating photovoltaic systems are becoming an expanding trend as its economy migrates to cleaner energy with higher efficiency. DC energy available from PV modules: The first step in analyzing the expected energy production from a photovoltaic system is to obtain an accurate estimate for the dc-energy available from the array, for the intended site and design configuration.

AC energy provided by PV system: Developing a fundamental understanding of the factors influencing the dc energy available from individual photovoltaic modules is a significant step toward that goal. The methodology of the PV system is presented in Fig. 2.

Obi & Bass (2016) presented the recent developments and trends pertaining to Grid connected Photovoltaic Systems. The PV industry is expected to continue to grow due to several factors like the falling prices of silicon and PV modules, technological advancements in large scale manufacturing, many governmental incentives, maturation and proliferation of favorable interconnection agreements and continued technological improvement of power converter technologies. There are many benefits of Grid Connected Photovoltaic System (GCPVS), such as its long working life (25–30 years), low operations and maintenance costs and obvious environmental advantages over fossil-fuel power plants. Xin et al. asserted that without the proper technical infrastructure, a large amount of PVs will have a negative impact on the electric grid's power networks.

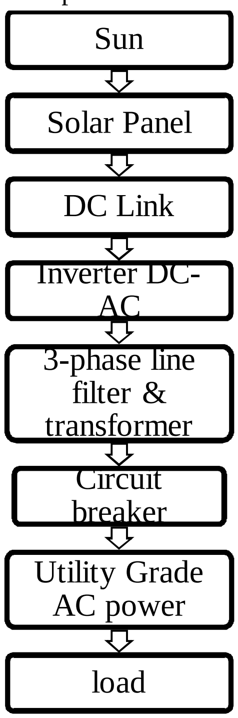

Fig. 2: Process of PV system

D. Biomass

The conversion of biomass into energy can be achieved in a number of ways. To provide a fuel suitable for direct use in spark ignition gas engines, the fuel must be provided in either a gaseous, or a liquid form. Biomass is the plant material derived from the reaction between CO 2 in the air, water and sunlight, via photosynthesis, to produce carbohydrates that form the building blocks of biomass. Typically photosynthesis converts less than 1% of the available sunlight to stored, chemical energy. The solar energy driving photosynthesis is stored in the chemical bonds of the structural components of biomass. If biomass is processed efficiently, either chemically or biologically, by extracting the energy stored in the chemical bonds and the subsequent ‘energy’ product combined with oxygen, the carbon is oxidized to produce CO_2 and water. The process is cyclical, as the CO 2 is then available to produce new biomass.

IV. CONCLUSIONS

Modern power system is a web of energy sources as the sources are integrated within the mainstream system for efficiency, reliability, and economy. Modern day concept of micro-grids provides a viable solution to overcome the challenges of integrating renewable energy sources and systems into the main-grid. Micro-grids are small scale electrical power generation and distribution systems interconnecting multiple customers, distributed generators and storage systems. The purpose is to addresses ongoing issues in resilient operation of smart grids that are penetrated by huge volume of renewable energy sources and systems. For high performance, economy and sustainability in addition to efficiency and reliability, advanced control-communication and monitoring technologies are required for realizing intelligent and scalable power system architecture.

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