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Optimization of renewable power system for a household in the UK

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Abstract: A distributed hybrid renewable energy system for a household is studied and evaluated based on the data of electrical consumption and renewable energy resources. The hybrid system is comprised of a wind turbine, PV arrays, a biodiesel generator, batteries and converters. The aim of this study is to design a renewable energy system with Solar Panels, Wind Turbines, biodiesel generators for a flat in the UK. The economic viability of the proposed hybrid renewable energy system has been analyzed.

Introduction

Distributed Hybrid Renewable Energy System (HRES) has great potential to benefit residences to possess cheaper, cleaner and flexible electricity to meet their demands. And the implementation of this kind systems would not only benefit themselves but also contributed to country and the whole environment. Many relevant literatures showed the feasibility of installation in the remote areas around the whole, but less mention that targeting to urban households no matter in the stand alone mode or gird connected.

The potential of domestic micro-generation was estimated by Energy Saving Trust to contribute mostly 40% of UK electricity demand by 2050 in 2005 [1]. And the UK government recognized the significant important role of distributed electricity generation to fulfil its renewable energy targets via formulating sustainable energy policies to sweep the barriers and providing incentives in 2007 [2]. Then to promote their developments, a series of reward mechanisms was introduced. Depending on the size, various incentives would be. To encourage the penetration of small-scale and low-carbon technologies applied in electricity generation, the fixed rate feed-in tariff (FITs) was introduced in 2010 to reward generators within a size of 5MW. It pays to the gross output of the generator including the surplus part that would export back to the grid. For large scales i.e. the accredited generators greater than 50kW, an incentive called Renewables Obligation Certificates obligate suppliers to buy renewable powers from renewable generators. But current FITs cannot maximize the benefit of distributed generations for lack of time-of-use component attributing to the uncertain yield of distributed generators. Thus metering time-varying export payments to micro-generators is the key task in the future [3].

Due to the complexity of distributed generator technologies and accessing small scales, the precise metering data of installed distributed generations cannot be gathered. Instead only in 2011 National Grid gave an estimation of roughly 9GW about the ‘embedded small and medium power stations, accounting for 11% of the total installed capacity. It is shown that except for the outstanding wind technology, other renewables are still in their infancy.

The aim of this study is to design a renewable energy system with Solar Panels, Wind Turbines, biodiesel generators for a flat in UK especially. The economic viability of the proposed hybrid renewable energy system has been analyzed.

Household Electrical Consumption

The load profile for households varies with time corresponding to the exchange of the day and night, the weather, the season together with the state of occupants’ activities and the usage of associated

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appliances, hence the demand in the short period would be steep, rapid and random. This throws out a challenge for designing a tailored distributed generator system to accommodate the dynamic load throughout the year. Thus the effectively monitoring and the precisely short-term predicting with respect to the power consumption would attenuate the challenge as much as possible via the assistance of the smart meter.

Smart meters could offer two-way communication i.e. collecting real-time consumption information, sending outage notification and receiving load control signals and integrate instantaneous power over any intervals. In the early time many power companies grabbed energy use data on an hourly or a monthly basis for bill purpose or a shorter interval-15mins as the standard for load analysis in the UK industry, nevertheless it is far from adequacy to explicit the load dynamic in the residential domain as the above stated reason. A range of minutely based high resolution i.e. 1min - 5mins demand modules for households were proposed to apply in on-site generations within these years [4]. Ref. [4] analyses the consumption data collected at 1 min intervals for seven houses in the north-west of England over half a year to perceive the nature of domestic electricity-profiles. Ref. [5] modules and simulates a stochastic model over 10-min intervals to reproduce the domestic electricity pattern based on the data set EL-SEA-2007. Apart from the hardly forecasted instantaneous power demand, a typical daily load profile can be summed up to sort into 5 time zones separated by two peak times, shown in the Figure 1 [6].

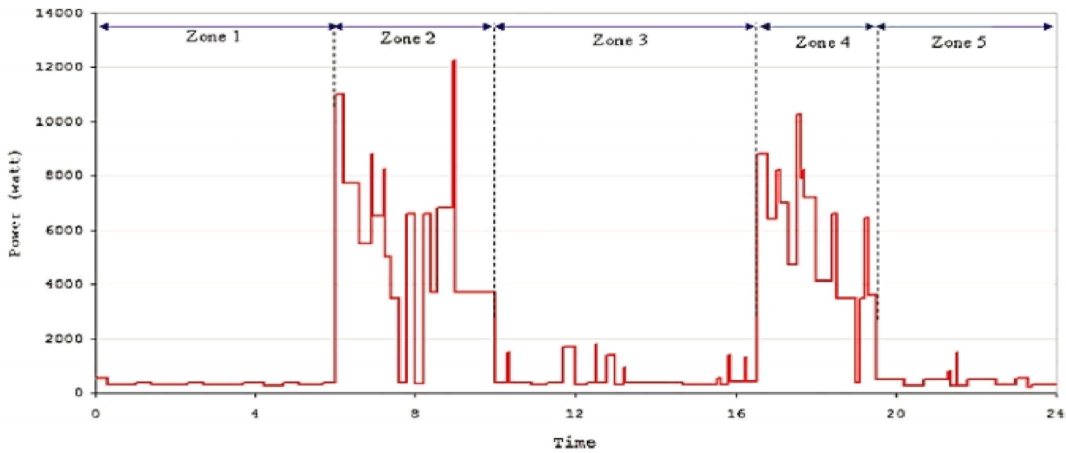

Figure 1 Typical load profile for the UK household

Hybrid Renewable Energy Systems(HRES)

Respect to the unpredictable and intermittent natures of renewable energy sources, hybrid renewable energy systems which terms to the incorporation of several renewable energy generations prevalently the combination of wind turbines (WT) and solar PV panels due to the complementary distribution throughout the year with energy storage systems (ESS) are highly favored and studied to provide the more stable and efficient energy supply [7]. It has been demonstrated that HRES possess higher class supply, better performance and more compact requirement for the storage capacity than single wind power systems or PV systems. The general configuration of renewable energy system is depicted in the Figure 2 below. HRES can be designed to operate in stand-alone or in grid-connected as mentioned previously. In the stand-alone mode, the specification with a sufficient capacity of the back-up energy storage is in need to level the unanticipated fluctuation of involved renewable energy sources via the stored energy. In the grid connected mode, ESS is not necessarily displayed in and even if it exists the capacity would be shrunk considering the grid can also act as the electricity container [8]. Moreover renewable energy sources are interfaced to a DC bus via DC–DC and AC–DC power converters while DC–AC inverters are responsible for distributing the active and reactive power to the grid [9].

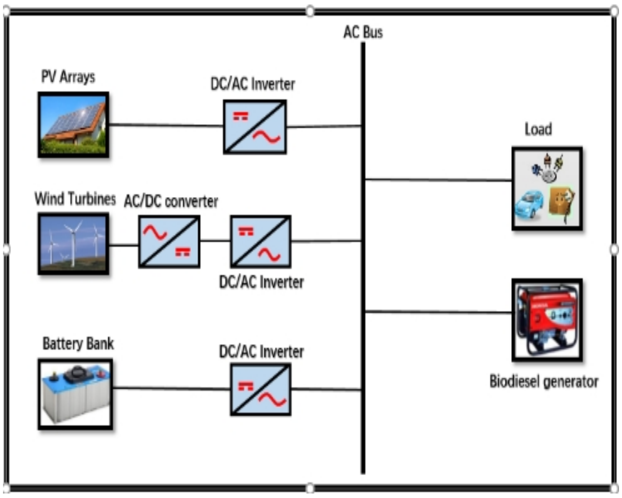

Figure 2 General hybrid RES configuration

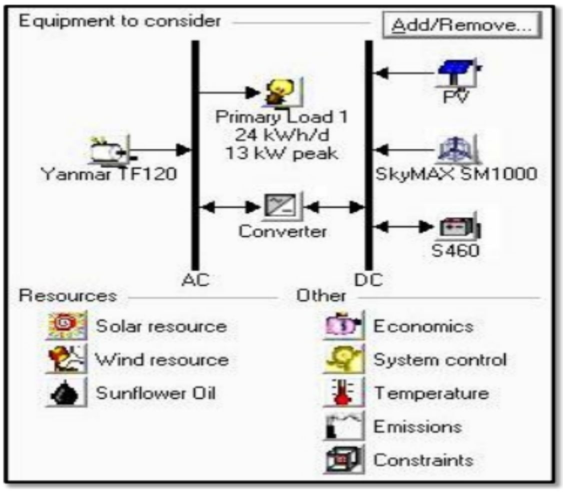

Figure 3 Simulation interface of Homer

Simulation for Stand-alone System

Hybrid Optimization Model for Electric Renewables (HOMER) is a software tool which installs a number of models modeling various renewable energy generation systems to get access to process a techno-economic feasibility evaluation for the design hybrid system. It includes three modes: the simulation mode, the optimization mode, and the sensitivity analysis mode. After simulation, the optimization result will be automatically arranged in sequence based on the Net Present Cost and the Levelized Cost of Energy. It can respond and evaluate any sensitive variation of component input to further analyze the reliability of the system. Both off-grid and on grid system can be set to simulate.In the stand-alone mode, a PV-Wind-Diesel-Battery system is proposed and simulated. Figure 3 introduces the simulation interface of HOMER.

In the upper working space, a schematic diagram of the system configuration is shown where each button can be clicked to fill detailed information for each component. In the lower space, information of relevant sources and other limiting factors can be typed in.

Due to the overwhelming status in the system, simulations of wind turbines with step by step escalated capacity would impose a more precise optimization for the system design. And specific component profile typed in the software are exhibited in Figures below. For PV panel SPR E19-240 , it has a derating factor of 99.75%, a temperature coefficient of -0.38%, and is mounted with a tilted angle of 52^{o} due south. The nominal efficiency at STC reaches to 19.3%. The minimized amount limits to 10 to ensure the certain essential portion of solar injection. All panels are interconnected in 2 series to build a double voltage output and maintain the original DC output current. For wind turbines, they connect to the DC bus via wind charge controllers not displaying in the window. And all systems are simulated at the scaled annual average wind speed.

Conclusion

To seek for the optimized configuration, the HOMER software was utilized to automatically simulate all viable configurations and rank them on the NPC and COE criteria. From simulation results, we can know that the wind-biodiesel engine-battery system was evaluated to possess the lowest NPC (59,854 dollars) and the lowest COE ($0.647 /kWh) while the second best system is the best one adding PV arrays.

As far as this study conducted, it can be concluded that due to the abundant wind resources, wind turbines have an overwhelming contribution to the HRES. To specify, facing a typical residential flat, the configuration with 2KW rate wind turbine would obtain a most economic cost which may be considered for middle income families.

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