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Modelling a reliable wind/PV/storage power system for remote radio base station sites without utility power

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Abstract

The development of photovoltaic (PV) cells has made steady progress from the early days, when only the USA space program could afford to deploy them, to now, seeing them applied to roadside applications even in our Northern European climes. The manufacturing cost per watt has fallen and the daylight-to-power conversion efficiency increased. At the same time, the perception that the sun has to be directly shining on it for a PV array to work has faded.

On some of those roadside applications, particularly for remote emergency telephones or for temporary roadwork signage where a utility electrical power connection is not practical, the keen observer will spot, usually in addition to a PV array, a small wind-turbine and an electrical cabinet quite obviously (by virtue of its volume) containing a storage battery. In the UK, we have the lions share (>40%) of Europe's entire wind power resource although, despite press coverage of the "anti-wind" lobby to the contrary, we have hardly started to harvest this clean and free energy source.

Taking this (established and proven) roadside solution one step further, we will consider higher power applications. A cellular phone system is one where a multitude of remote radio base stations (RBS) are required to provide geographical coverage. With networks developing into the so called "3G" technologies the need for base stations has tripled, as each 3G cell covers only 1/3 the geographical area of its "2G" counterpart.

To cover >90% of the UK's topology (>97% population coverage) with 3G cellular technology will requires in excess of 12,000 radio base stations per operator network. In 2001, there were around 25,000 established sites and, with an anticipated degree of collocation by necessity, that figure is forecast to rise to >47,000. Of course, the vast majority of these sites have a convenient grid connection.

However, it is easy to see that the combination of wind and PV power generation and an energy storage system may be an interesting solution for the more rural and remote applications – particularly those where an electrical supply is not available or practical – and this paper attempts to explore the current practicalities of such a power generation solution for those cellular phone base stations.

Keywords: Wind; Photovoltaic (PV); Radio base stations; Remote sites; Off grid; Hydrogen storage

1. Introduction

The development of photovoltaic (PV) cells has made steady progress from the early days, when only the USA space program could afford to deploy them, to now, seeing them applied to roadside applications even in our Northern European climes. The manufacturing cost per watt has fallen and the daylight-to-power conversion efficiency increased. At the same time, the perception that the sun has to be directly shining on it for a PV array to work has faded.

On some of those roadside applications, particularly for remote emergency telephones or for temporary roadwork signage where a utility electrical power connection is not practical, the keen observer will spot, usually in addition to a PV array, a small wind-turbine and an electrical cabinet quite obviously (by virtue of its volume) containing a storage battery. In the UK, we have the lions share (>40%) of Europe's

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entire wind power resource [1] although, despite press coverage of the "anti-wind" lobby to the contrary, we have hardly started to harvest this clean and free energy source.

Taking this (established and proven) roadside solution one step further we will consider higher power applications. A cellular phone system is one where a multitude of remote radio base stations (RBS) are required to provide geographical coverage. With networks developing into the so called "3G" technologies the need for base stations has tripled, as each 3G cell covers only 1/3 the geographical area of its "2G" counterpart. In the UK (if not elsewhere), the competition between service providers is both intense and fiercely cost cutting. By October 2003 [2], the largest four mobile phone operators shared the market in a very approximate 35/25/25/16% proportion and that market was, to all intents and purposes, 100% penetrated – 50.2 million active consumer accounts versus the 58.8 million population of the UK. Having paid huge sums to the government for the operating licences the downward pressure on capital and operational expenditure is constant, whilst the fierce competition restricts most cooperation on sharing an infrastructure.

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However, it is easy to see that the combination of wind and PV power generation and an energy storage system may be an interesting solution for the more rural and remote applications – particularly those where an electrical supply is not available or practical – and this paper attempts to explore the current practicalities of such a power generation solution for those cellular phone base stations.

2. The load

2.1. Electrical

The load that has to be supplied by the power system is, naturally, continuous on a $24 \times 7 \times 52$ basis and comprises the cell transmission equipment, microwave link and any required energy for ambient control—heating and cooling. The equipment has traditionally been 48 V dc with a 4 h battery back-up but recent trends, both technically and commercially driven, have seen the introduction of ac powered loads (requiring UPS) and the acceptance of much shorter battery autonomy times (as low as 20 min). Note that the availability of the mains power in the UK is such that grid failures lasting longer than 20 min in the South East urban conurbations are, statistically, more than 6 years apart.

The size of the radio transmission (RT) load has been steadily falling and is forecast to fall further. Originally the forecast power consumption for 3G RT equipment was in the order of 10 kW and, with the colocation of 2G for an overlap period, many operators planned for up to 15 kW per base station. In reality, the loads have not been seen to be higher than 5 kW for a fully populated base station. For the future, it is safe to assume that power-to-transmission power efficiency will steadily improve—bearing in mind that the aerial power is in the order of tens of watts rather than hundreds. An overall design figure (including cooling) of 4 kW for a high power 3×3 sector aerial system is now expected to be conservative. It should be noted that when planning engineers were anticipating 12–15 kW for the RT and microwave load the mechanical cooling added a further 4–5 kW, resulting in each site requiring up to 20 kW of supply capacity.

2.2. Mechanical

The load has also been influenced by the mechanical solution to base station deployment. Traditionally the RBS looked as that illustrated in Fig. 1, a "walk-in" cabin, and most included mechanical cooling via some form of air conditioning plant. With local opposition increasing, fewer planning restrictions on enclosure volumes below 2.5 m^3 and the new availability of "outdoor enclosures" the face of the UK's RBS rollout program has changed.

Fig. 2 shows a typical outdoor enclosure with, in this case, 16 kW of dc power, empty space for the RT equipment and inbuilt heat exchanger in the door.

Some operators, for reasons of both capital cost and operational expenditure, historically decided to take technical "risks" in two significant areas both related to cooling.

The "perfect" solution addresses both the RT electronics and the battery, and that are temperature and humidity control via some form of precision air conditioning. This avoided the need for dragging in fresh-air (with damp and air-borne contaminant problems) and maintained the battery temperature at 20–25 °C for optimum service life. Some operators

Fig. 1. RBS cabin and mast.