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## Recent research on Energy Trading

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**Abstract.** Breakthroughs in the smart grid and promotion of "green communication" have encouraged wireless communication network to harness the local environment's resources and to function economic and ecological benefits in an energy-efficient manner. This paper presents a contemporary review of recent advancement of energy trading including renewable energy sources, types of energy trading and the advantages of having energy trading.

### 1. Introduction

Cellular operators have deployed denser base stations (BSs) with an increasing frequency reuse factor to provide higher capacity for subscribers due to the explosive increase in mobile data traffic. This lead in more severe inter-cell interference (ICI) and may result in a bottleneck for the network throughput [1]. Consequently, all the base stations (BSs) would have a high overall energy consumption by growing number of BSs. It would add significantly to cellular network operating costs and adversely to global carbon footprints [1-2]. The volume of traffic for emerging fifth generation (5G) systems is expected at tens of exabytes per month, and the capacity of 5G networks is estimated to be 1000 times higher than that of current cellular networks [3-4].

Among the solutions proposed to address this issue, equipping BSs with energy harvesting devices that can generate energy from environmental sources, such as solar panels and wind turbines, is a promising solution because renewable energy generation costs are generally lower than traditional energy from the grid [1, 2, 4-6]. Energy efficient techniques such as ON / OFF BS switching [2, 4, 7, 8], online data scheduling and power control [2, 4] have been suggested to minimize and delay power consumption or improve network capacity. Up to 10,000 kW of renewable energy have been used to power cellular networks, complementing the grid for continuous electricity supply [2, 6, 9]. Nevertheless, the non-compliance, unpredictability, and uncertainty of external energy sources in the natural environment make communication networks difficult to provide reliable power supplies.

In this paper we intend to present a contemporary survey of the recent works for the energy trading in C-RAN. Most of the previous surveys only focused on particular area for energy trading in C-RAN. The authors in [5] focused the works on design for real time energy trading in downlink green C-RAN. By introducing three real-time energy trading strategies, which are power-shortage management by partial cooperation, power-shortage management by full cooperation and overall network energy management by full cooperation. Moreover, the authors in [4] present a review of recent work on the redistribution, utilization, trade and planning of energy harvesting. This paper discusses the operating methodology and optimization constraints. In contrast, the recent development of a resource allocation



framework that considers renewable and on-grid energy management, channel allocation and transmission control over the Hybrid Energy Supplies CRAN (HES-CRAN) were being investigated in [10]. This paper also proposed an online algorithm to strike a balance between customer profit and cost in grid power selection, while preserving the data queue and reliability of energy in radio units (RUs).

Instead of focusing on specific problems, this paper provides a review discussing about various aspect for energy trading in C-RAN and also the potential co-evolution of communication system and smart grid. The reader will get a clear explanation and complete picture of the latest research in this area.

## **2. Renewable energy sources (RES)**

Energy harvesting (EH) also known as energy scavenging is the transformation of environmental energy into electrical energy for use in electronic devices or circuits. Up to 10000 KW of renewable energy sources per base station can be generated to augment persistent supplies from conventional power grids and cellular systems. EH has been widely used using several sources of energy. It consists of absorbing ambient energy to use it immediately or later [4, 11]. There are plenty types of renewable energy sources (RES), such as wind energy, solar energy, thermal energy, biomass energy and mechanical energy [ 4, 11-14].

### *2.1. Wind energy*

Wind power involves the conversion of wind energy into electricity by using wind turbines. Wind turbines capture the wind, which is then producing renewable energy sources. A magnet passing through a stationary coil known as a stator transforms the wind power into electricity. AC power consumption occurs when the magnet moves through the stator. It then converts to DC electricity. The output of rotor speed is used to track maximum power point. The rotor's frequency data is transmitted to the voltage converter (FV) which produces the required voltage signal [4]. Normally, a rotor with a diameter of 1m can produce around 85W - 100W of electric power at a wind speed of 8 m/s [4, 12].

### *2.2. Solar energy*

The most preferred environmental renewable energy sources is solar energy that has been applied extensively to various applications and technologies [4, 10-11, 15]. Thanks to its power density, flexibility and efficiency, solar energy is very common nowadays. It is the process of capturing and storing solar energy emitted from the sun. Solar or photovoltaic, cells directly convert sunlight to electricity and then acts as a supply of energy to self-supporting devices. The resulting DC (direct current) electricity is then transferred to a power inverter to convert it to AC (alternating current), which is the process in which electricity is supplied to others. It is predictable but uncontrollable. Timings of day and season, sunrise and sunset can be predicted fairly accurately. Generally, amount of solar energy is about 100 mW/cm<sup>2</sup>, but it requires direct light exposure which limits its indoor use [4, 11].

### *2.3 Thermal energy*

Energy can be generated quickly from a variety of thermal sources, such as animals, humans, and machines by using thermal generators[16]. Energy harvesting can be used for thermal effects which generate electricity using the difference in temperature. In general, when their junctions are placed under different temperatures, voltage signals can be created between two conductors made of different materials. It has a low efficiency which is 5 to 10% [17,18] and requires a 30C for temperature difference. For this case, the power density is around 135 mW / cm<sup>2</sup>, at 10C [11].

### 3. Energy trading Approaches Schemes

#### 3.1 Two way energy trading

Power grids are also undergoing a revolutionary transition along with the development of cellular networks. New smart technology is expected to be supported by the growing smart grid that enables it to use smart meters. Electricity bills of cellular operators continue to rise because of higher demands in the 5G and beyond for wireless services[4]. In addition, with the development of smart grid technology, two-way energy and information flows between distributed charges and the grid become feasible to enable more energy efficient power networks. BSs in cellular networks may be able to engage in two-way energy trading with the grid as a specific type of energy load to make local renewable energy more efficient in order to save energy costs [1].

Through integrating renewable energy sources, BSs are looking for new solutions to reducing energy expenditure [4]. With the advancement of smart grid technologies, each RRH with local renewable energy generation enables the implementation of two-way smart grid energy trading. In contrast to the traditional one-way energy flow from the grid to the receiving terminals, the smart grid uses smart meters to enable both two-way energy and information flows [24-26]. With the implementation of two way energy trading, the renewable energy BSs can purchase additional energy deficits to sustain stable operations and sell their excessive renewable energy for profit to the grid, which is a simple way of saving operating costs [1, 2, 4]. In the case of a shortage of renewable energy, the RRH may request the sum of the grid's energy deficit to sustain its stable operation and, instead, may make a profit by selling the excess energy to the smart grid at the agreed price. It helps to balance the electricity demand and reduce the pressure on the grid and thus increase the stability of the grid [2].

#### 3.2 Dynamic energy trading

DET enables for the negotiation and sharing of energy between multiple wireless powered devices (WPDs), with temporal and spatial differences in their energy harvesting processes. In the case of DET, WPDs who earn more energy than they can consume can give their excess energy to those who cannot get sufficient energy to provide the necessary services [27].

Energy prices are expected to exhibit strong dynamics in the smart grid as a result of intermittent renewable energy. Dynamic pricing is important for regulating energy requirements and for encouraging users, such as 5G networks, to consume energy wisely and efficiently. The prices of both sales and purchases of energy fluctuate over time to reflect demand for energy in real time and availability of supply [2, 6]. DET makes it possible for WPDs with different harvestable energy to help each other and thus to further improve the reliability of the power supply for wireless powered communication networks. In addition, most of the existing works are focused on the transition of wireless power from a specific energy source to a fixed energy receiver. DET enables for the dynamic exchange of energy between different WPDs with different harvestable energies. This can reduce energy consumption and increase the energy efficiency of wireless power systems without requiring investment in dedicated power supply infrastructure [6].

#### 3.3 Multi-timescale energy planning

Multi-timescale energy planning is one of major potential to reduce the operational expenditure of 5G. Therefore, research on the development technique for improving a new framework for 5G is of great importance. The most recent work conducted on improving the new framework which is multi-timescale energy planning are discussed here below.

5G and smart grid interoperability needs to be supported across multiple different timescales (i.e. grid-energy pricing, energy harvesting, and wireless transmission) [2]. The different timescales are due to the physical characteristics of wireless networks and energy harvesting, the time-varying demand and supply across smart grids and the marketing strategies of electricity utilities companies which is the timescales for smart grid energy pricing are regulated by electricity utility companies, depending on demand, supply and marketing strategies. Different business models and contractual arrangements can

be made. Long term pricing, lasting up to days or months, reflects medium-to long-term demand and supply and changes in the fuel market. On the other hand, short-term pricing reflects changes in demand and supply in real time. The wireless timescale can be used as the wireless transmission drives the changes. Extensive simulations show that it is possible to save up to 58% of MTEP energy costs[27].

#### 4. Advantages

Cost savings and profitability are the catalyst for the consumers. Distribution, storage and exchange of energy will improve overall grid operating efficiency, decrease network operating costs and reduce greenhouse gas emissions.

##### 4.1 Decrease network operating cost

Demand response allows users to minimize or shift their consumption of electricity during peak periods based on a time-dependent price [19-21]. Utilities use fast start-ups, high operating costs and typically gas generators to meet high demand for electricity during peak hours, around 10% of the day. Using the proposed adjustable power method, the operating costs of the system decreased by 6.38% on a weekday and 4.79% on a weekend day, i.e. cost savings, respectively [22].

##### 4.2 Improved the system efficiency

The proliferation of distributed generation, storage systems and the capability of electric vehicles to store large amounts of energy enable network operators to provide a variety of ancillary services to increase grid efficiency [19, 20]. In addition, the demand for energy trading users will be met locally and the use of remote high-capacity generator options will be reduced. This will reduce transmission line congestion and minimize the loss of the same line. This upgrade would increase system reliability and reduce the average cost of customer interruption.

##### 4.3 Reduce greenhouse gas emissions (GHG)

Countries around the world set goals to reduce GHG emissions in the decades to come. The UK Government is committed to reducing carbon emissions by 80%, relative to the baseline of 1990, by 2050. Combined heat and power (CHP) is a method used for exploit heat products that can contribute up to 80% of the total energy consumed during generation of electricity [23]. It is shown in [19, 23] that CHP can improve efficiency by 30% and provide significant energy savings of more than 50% compared to traditional power generation, with additional CO<sub>2</sub> emission reductions per capita.

#### 5. Conclusions

In this paper, the energy trading was studied, discussed and summarized. Unlike other existing surveys focused on a specific area of energy trading, this study looked holistically at energy trading to cover research areas. Specifically, we conducted a comprehensive review on the state of the art of energy trading and then summarized it in three parts, namely renewable energy sources, types of energy trading and their advantages.

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