**Master project with Ericsson**

**Reducing running costs of radio base stations with electrical batteries**

**Introduction**

Ericsson company, one of the major world telecom equipment manufacturers, is developing Radio Base Stations (RBS) to provide high-speed mobile communication services. Apart from the transmission and control equipment, most RBS also possess backup batteries for the case of interruption of the power supply. One of the principal components in Total Cost of Ownership (TCO) of RBS is the energy cost which may vary significantly within hours, days, and months, see Figure 1. If the price is known in advance or it can be accurately predicted, the battery can be charged when the price is relatively low and then discharged to power the equipment when the price is high thus reducing TCO.

![Figure 1 Data collected from Vattenfall](link)

From a sustainability perspective, it is also good to charge the batteries when the price is low since this usually means that available amount of energy produced by windmills or solar cells is large. Also, by taking some of the energy from the batteries at daytime, a more even load on the grid can be achieved. Hence, the power grid doesn’t need to be dimensioned for the worst case (peak) scenario.

**Plan of research**

Many factors determine TCO: electricity prices, power consumption, operational, system maintenance and other costs. It is reasonable to concentrate on the first two components as the most relevant to the goal of the project. The consumption is driven by the workload of the RBS, historical data are available. The electricity prices have clear seasonality patterns: there is a clear day cycle (the prices are generally cheaper at night and peaking around 8 and 17 hours), then a weak and a year cycle (weekend prices and summer prices are generally cheaper). Per day and per week battery use policies allow for optimisation of current costs while optimisation over a year period is more relevant to long-term investments and dimensioning of the whole system.
The first stage of the project is to derive an optimal daily policy of the battery usage. The electricity prices for every hour are known for one day ahead: these are dictated by the market of future contracts. The consumption demand for a day ahead is not known but can be relatively accurately predicted from historical data, see below on how it can be done. A mathematical model then can be formulated in terms of a Markov decision process where the available actions are switching the battery between the states: idling, charging, and discharging. The goal function to be minimised is the electricity consumption as a function of hourly electricity prices, consumption, and the battery power level. Constraints are given by the physical limitations of the battery: capacity, maximal and optimal discharge current, time to recharge, the lowest acceptable remaining charge (the battery should still be possible to use as a backup for power outages). Finding an optimal policy involves Bellman-Ford type of algorithms on a graph. The main result of this part would be a software tool to optimise the battery switching for one day ahead. But also, a first estimate to the optimal level of the battery power to be maintained at the end of the day cycle. This is done by applying the found optimal daily policy to the available historical data and comparing it to the ideal optimal policy derived for a week, a month or longer if the prices for such longer periods were available at the beginning.

The second stage will look at the week and the month cycles. The main challenge here is that the electricity prices are not known for so much time ahead and thus should be modelled. The same applies to the RBS energy consumption also. Specifically, we aim to construct models for:

- Energy price as a function of time in a specific geographical area (for instance, Sweden is divided into 4 areas with different price for electricity). The price is heavily affected by the weather: temperature, solar irradiation, wind, precipitation and water levels in lakes and rivers. Currently existing models are very complicated and have commercial interest, but some initial approach can be done by employing Deep Learning (DL) algorithms on a neural network.
- Power consumption in the RBS as a function of time. DL approach is also suitable here and is more straightforward than for the electricity price modelling.

At such time horizon, additional constraints should be considered: the running costs of the battery: min, max charge, loading cycles, lifespan, deterioration of capacity, replacement costs, etc.

Several factors are to be considered and questions answered for successful implementation of the described approach on the network operator level.

**Where Shall the Algorithm Execute?**

This type of algorithm can either execute in the RBS or as a central function somewhere else in the RAN (cloud?). I.e., can one keep the models good (and generic) enough to execute centrally controlling many nodes or is continuous training for each RBS instance needed making it more efficient to run locally. This question also addresses more SW related aspects, such as:

- Resilience
- How much signaling that is required.
- Required amount of memory and CPU cycles
What is the optimum size of batteries?

The optimum size of the batteries depends on several things:

- Power consumption of the RBS.
- How much of the power consumption shall come from the batteries when the energy is expensive?
- How long time is the energy usually expensive?
- Volatility of the price in one day, week or in a longer period of time?
- Replacement cost of batteries
- Lifespan of batteries in this type of scenario.

It is quite difficult to select the optimum size batteries. A tool could probably be very useful for helping an operator to select size of batteries.

Estimate business case for network provider.

Historical data can be used to investigate how much money that can be saved for different types of RBSes (small, medium, and large) and for different sizes of network. **Note:** A network can contain any number of RBSes from 50 to tens of thousands. This information can be used for estimating business cases for operators.

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