# BATTERY SIMULATION WITH DC POWER SUPPLY R&S®NGM200

**Products:**

- ► R&S®NGM201
- ► R&S®NGM202
- ► R&S®NGM-K106

- ► R&S®NGU201
- ► R&S®NGU-K106

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# Contents

# 1 Overview

This application note is about creating your own battery model for the R&S®NGM200, beyond the standard models provided within the battery simulation option NGM-K106. The main purpose is to gradually discharge a battery or a rechargeable battery using the internal QuickArb function. The discharge of the battery can then be recorded using the fast data logging functionality FastLog. The recorded data are stored in a .CSV file. This file can then be adapted to be used as a battery model in the battery simulation mode of the R&S®NGM200. For this purpose, Rohde & Schwarz provides a tool for developers to make their work easier. This tool calculates all the data required for a battery model. The following chapters describe the procedure from building an arb file up to working with the tool.

This application note applies likewise to R&S®NGU201.

# 2 Battery characteristics

The simplest way is to consider a battery that powers an electronic circuit as a basic ideal voltage source.

Batteries are quite dynamic energy sources and the voltage of a battery is hardly constant - it varies depending on the state of charge, load, temperature, the age of the battery and much more. Think of a car battery on a cold winter's day, which may have difficulty starting the car, while on a warm summer day this would normally not be a problem.

The reason for this is that the battery itself performs through chemical reactions that are influenced by several factors. The geometry of the cell, the surface of the electrodes, the temperature of the reactants, the diffusion rate within the electrolyte and many more, all affect the reaction speed of the battery. Hardly any value remains constant in the battery while the battery is discharging or the outside temperature changes. Due to this dynamic behavior, the simulation of a battery requires a good model.

With the R&S®NGM200, developers can simulate the behavior of a battery under different conditions and requirements. As a result, early in the R&D cycle, essentially a real battery can be used.

The selection of batteries or rechargeable batteries during the development of various battery-powered products is often a challenge. However, with the essential requirements, the characteristics of available batteries can be compared or selected with the battery requirements. Only seldom does a battery system fulfill all requirements. Consequently, the selection process usually involves compromises between the different battery properties. The R&S®NGM200 can make it easier for the developer of a battery-powered product to select the right battery.

However, the first step is to understand all the important parameters and to apply them to the respective product requirements and applications. Some of these parameters are described below. Section **Error! Reference source not found.** Testing the Battery Model explains how to simulate or replicate these parameters with the R&S®NGM200.

## 2.1 Open Circuit Voltage

The cell voltage varies with the selected chemical composition. Depending on the application, choosing the right battery with the right cell voltage can affect the efficiency and complexity of the power electronics circuits in the device. Batteries are marked with a nominal voltage - however, the open circuit voltage of a fully charged battery can be 5 to 7% higher.

## 2.2 State of charge

The State of Charge (SoC) is defined as the level of charge of a battery relatively to its capacity in percent. If the battery is fully charged, the SoC is 100%.

## 2.3 Temperature

The charging and discharging temperature of the energy storage cells is very important as DUTs are often used in harsh conditions. At high temperatures, for example, the self-discharge rate increases significantly. At low temperatures the internal resistance increases. Zinc-carbon and alkaline batteries are not normally used for operation below 0°C. Lithium cells can operate down to -40°C, but with significantly reduced performance.

## 2.4 Internal resistance (ESR)

During the discharge cycle, the internal resistance remains comparatively constant, and the internal resistance rises sharply towards the end of the discharge. As a result, the internal resistance strongly contributes to the heating during charging or discharging and thus converts power loss. The R&S®NGM200 can fully simulate the variable internal resistance, depending on the state of charge. The following figure 1 illustrates an example of a battery. If the SoC drops, the open circuit voltage also decreases, but the internal resistance increases.
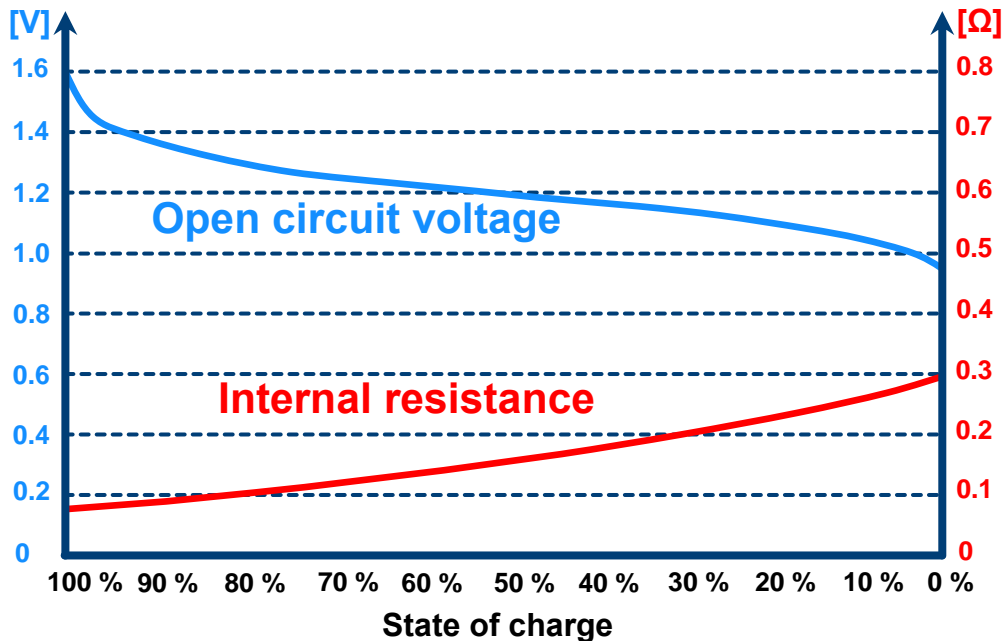


Figure 1: Example of the increasing internal resistance over the state of charge

## 2.5 Durability

The durability of a battery is the period of operation between the time of delivery and the time at which the battery falls below predefined values due to aging. However, the durability of a battery depends on several factors such as battery type, state of charge of the battery, ambient temperature, number of cycles and the depth of discharge. The self-discharge rate increases with the temperature. Most manufacturers' specifications are given at room temperature, so developers are advised to check the battery's properties. The service life of a battery can then also be calculated for the specific environmental effects or simulated and tested with a battery simulation.

# 3 Battery Model

This chapter is about creating your own battery model. Thereby it is described step by step how to proceed. Rohde & Schwarz also provides a tool that supports the developer in creating the model. To simulate or build a battery model, the NGM-K106 option is required. You can find the ordering information in chapter 6.

## 3.1 Battery Model Editor

To define a specific battery model, the battery data can be entered conveniently using the built-in battery model editor. The battery model editor allows you to create and edit battery models with custom behavior. In the editor, the open circuit voltage (Voc) and the internal resistance (ESR) can be defined for different states of charge (SoC) of the battery [1]. Data sets for the frequently used battery types, like Lead, Li-Ion, NiCd and NiMH are already available as preconfigured data sets. These can be easily modified and thus adapted to the requirements of a specific application. Additional battery data sets can be loaded from a USB stick and stored on the hard disk of the R&S®NGM200 power supply unit. The following steps describe the procedure for loading a data set for battery simulation to the NGM200.
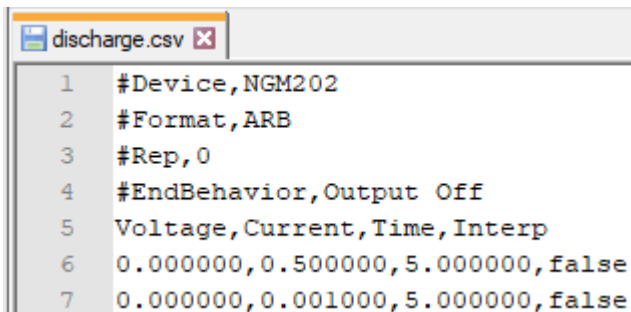
The Battery model editor can be accessed from the device menu. After activating the editing mode, you can select whether you want to create a new battery model or load a saved file. The R&S®NGM200 loads the selected battery model file into the battery model editor.

## 3.2 Building a battery model

For the battery model, three steps are necessary to create this. First, a battery must be discharged. Then this data needs to be logged. After that, the tool that calculates the battery model is used.

### 3.2.1 Building the Arbitrary File

In order to get from your battery to your battery model you have to perform a discharge test. A battery must be discharged in stages to be able to determine the internal resistance and the varying open-circuit voltage versus the state of charge. To achieve highest accuracy, the built-in QuickArb functionality can be used to generate the required discharge load profile with the internal timer. After opening the Arb Editor on the device, it can be adjusted with the following cycle. A 10 second cycle with 0.5 A discharge current for five seconds followed by 1 mA discharge current for 5 seconds. This ensures that the open circuit voltage can be determined during the discharge. The following figure shows the arbitrary-file used for the characterization of a Li-Ion battery which was used for illustration in this application note:



```
  📄 discharge.csv ☒
  1     #Device,NGM202
  2     #Format,ARB
  3     #Rep,0
  4     #EndBehavior,Output Off
  5     Voltage,Current,Time,Interp
  6     0.000000,0.500000,5.000000,false
  7     0.000000,0.001000,5.000000,false
```

Figure 2: Battery discharge Arb-File

The discharge current should be modified according to the own use case. Note that the average discharge current over the cycle is only half the value entered.

Open the channel menu and select the channel connected to the battery. Now the arbitrary function configuration must be selected and the following window appears:
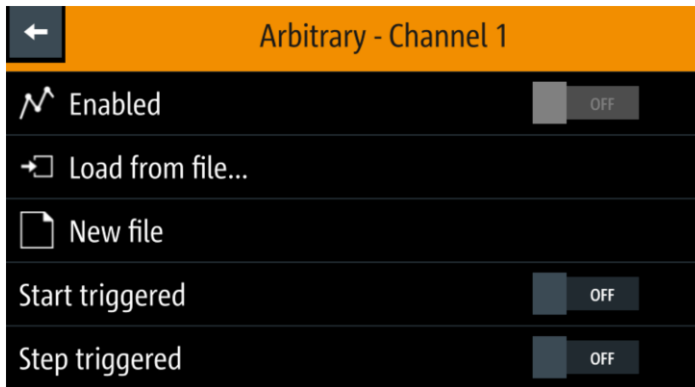


Figure 3: Arbitrary Settings

To load the generated file to the R&S®NGM200, the file must be saved to a USB memory stick. The USB memory stick can then be plugged into the USB port of the NGM. Now the file can be selected via "Load from file". As soon as the button "Enabled" is pressed, the function is activated on the respective channel and the arbitrary symbol appears on the screen.

Once you have made the settings, you can save them and connect the selected cell to the channel of your choice. Using a four-wire remote sensing setup will increase the accuracy of your results.

### 3.2.2   Prerequisites

To run the Battery Modeling Tool, a few steps have to be done previously. A Python environment needs to be installed. The open-source software Spyder IDE[1] from Anaconda is recommended. Here you do not have to make any settings and the following steps do not need to be followed.

If you have a Python IDLE, the following steps have to be done. To run the tool properly, the following libraries have to be installed:

► xlsxwriter

► matplotlib

► scipy

To install the libraries, the following command must be entered at the command prompt (cmd) for each library.

► C:\User\> py -m pip install yourlibrary

Once all libraries are installed, you can proceed with the next step.

### 3.2.3   Recording the data

After the arb file is created and setup, the discharge is recorded with the integrated logging function.

Activate data logging and select an interval (reciprocal of sample/s). The data can be stored internally or on a USB memory. Initiate the desired channel to start discharging the battery. An automatic current range should be used for the measurement.

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[1] https://www.spyder-ide.org/

In order to employ the log-file-data as battery model, some computing effort is required. Rohde & Schwarz provides a python-tool[2] that calculates the state of charge (SoC), the internal resistance and the voltage parameters from the discharge log file and generates a .CSV file with the corresponding battery model. The following steps describe how to use this tool.

First, save the tool as well as the log-file data on a computer. After the presetting has been made, the Python tool can be started. An Explorer window opens, in which the relevant .CSV file needs to be selected. Afterwards, the window "battery model tool editor" opens which allows to setup general variables for the battery model. It is shown figure 3:
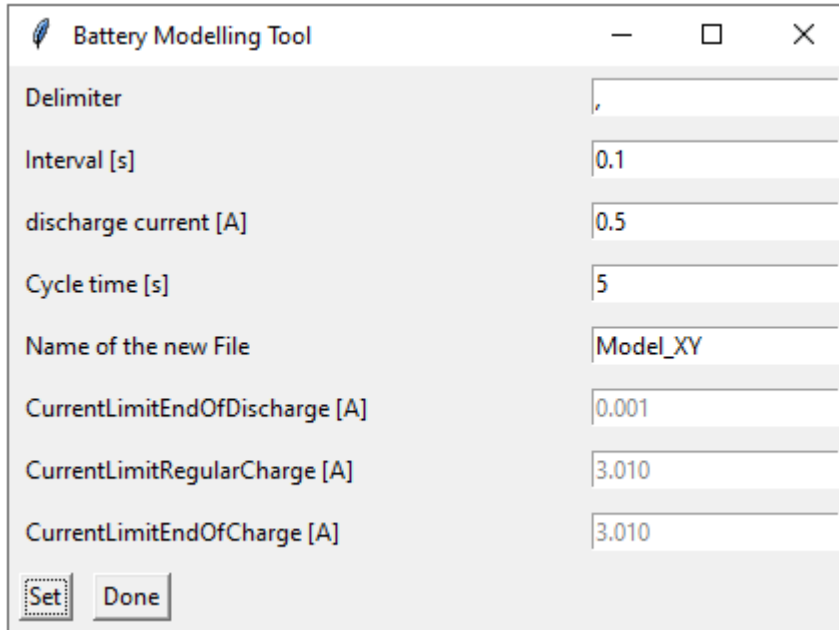


Figure 4: GUI of the Battery modelling Tool

In this window you have to enter values which are needed by the tool to calculate the battery model and to create the CSV file respectively. The delimiter must be adapted to the CSV format with which the log file was created or saved. A semicolon is required for the European format and a comma for the English format. Then the interval is required. For example, if a sample rate of 10 samples/s was selected for the log file, a 0.1 must be entered here. The discharge current with which the battery was discharged must be entered in the column provided for this purpose. A cycle time is needed with which the Arb-File was built up. Afterwards a name for the new .CSV file is required. The device with which the measurement is made must be written in the line provided for this purpose. The initial SoC needs to be set to the value that wants to be used as initial data. The last three rows are about the current limitation of the device. These are occupied with preset values, which are stored in light grey in the input field. If you want to change them, write the desired value in the respective input field. If not, it should be left empty. With "Load" button the entered data are saved and displayed in the Console. The window can then be closed by clicking the "Done" button. Now the program starts and a plot is displayed, which shows the battery specific data in diagrams. The following figure shows the plot of a sample file:

---
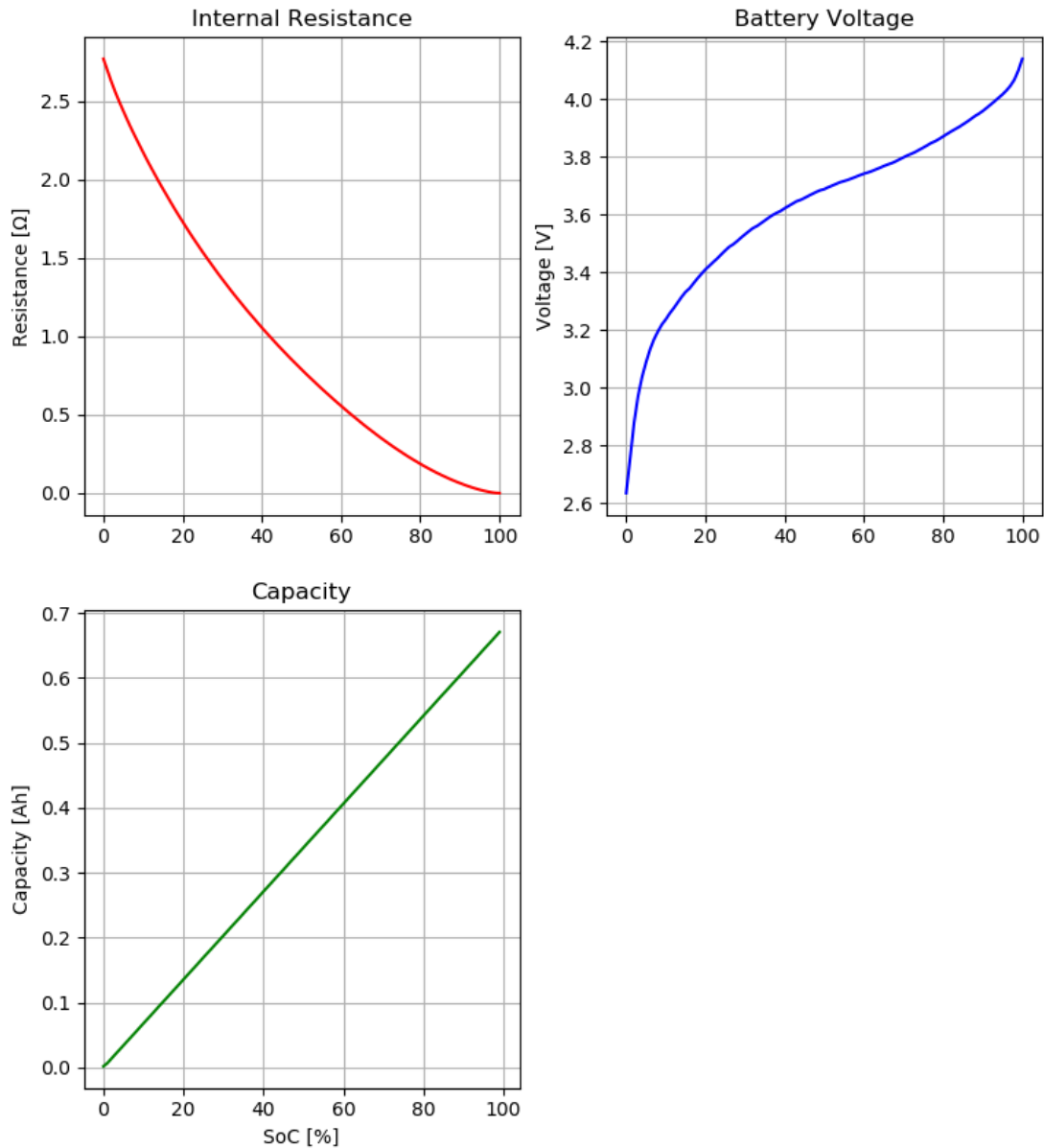
[2] Python 3.7 environment needed

Figure 5: Plot Battery modelling Tool

Finally, you get a Microsoft®Excel file, which contains the values of the internal resistance, the state of charge and the battery voltage. This file is stored in the same location as the tool with the previously defined name.

### 3.2.4   Preparing the File

For the simulation you only need the SoC and the corresponding voltage and internal resistance of your battery cell. The data is saved by the tool in an Microsoft®Excel file to make post-control of the data easier. Once the data has been verified, a .CSV file may be created. The R&S®NGM200 can load files separated by comma or semicolon. This must correspond with the settings of the NGM. In the "CSV-Setting" of the R&S®NGM200, the delimiter can be selected. Also, the decimal separator can be selected. To open the file

on the R&S®NGM200, it must be saved to an USB stick. The following figure shows an excerpt from the finished .CSV file:



```
Model_XY.csv ☒
   1    #Device;NGM202;
   2    #Format;BATTERY;
   3    #Capacity;0,677128099;
   4    #InitialSoC;100;
   5    #CurrentLimitEndOfDischarge;0,001;
   6    #CurrentLimitRegularCharge;3,01;
   7    #CurrentLimitEndOfCharge;3,01;
   8    SoC;Voltage;Resistance
   9    1;2,649614213;0,000675315
  10    2;2,77306288;0,001957624
  11    3;2,863857868;0,005439935
  12    4;2,924850427;0,01025949
  13    5;2,983103448;0,015890427
  14    6;3,027248731;0,022295273
  15    7;3,061653144;0,02957669
  16    8;3,080416222;0,0373134
```

Figure 6: The finished .CSV-file

In this example the .CSV file was saved with the semicolon as delimiter. This means that the format of the R&S®NGM200 must be checked for consistency. The .CSV file can then be stored to a USB memory device and transferred to the R&S®NGM200.

# 4 Testing the battery model

After you have measured and recorded the real data of your battery, you can open it in the battery simulation of the R&S®NGM200. With the integrated USB interface, the stored data can be easily loaded from an USB storage. In the dialog window you can activate the Editor mode. Now you can select the battery model file on your USB storage. The R&S®NGM200 loads the selected file into the battery simulation. The loaded parameters from the file are reproduced by the battery simulation. Now you can set the SoC, with which you want to start the simulation and the capacity of your battery.



Figure 7: Simulation of the Battery Model

# 5 Conclusion

Batteries are dynamic energy sources whose behavior in many cases deviates from an ideal voltage source. A model with a dynamic internal resistance, which changes depending on the state of charge, is used by R&S®NGM200 to simulate batteries. By using a load step method, it is possible to derive the parameters required to create a battery model file for the R&S®NGM200. With a little effort in Excel any battery model can be simulated. While the battery model itself is simplified and understanding is necessary to ensure proper use, the resulting effect is that we are able to emulate e.g. a Ni-MH cell very accurately. It requires relatively little effort to build the battery model. Thus, the developer is relieved of some work.

# 6 Ordering Information

| Designation | Type | Order No. |
|---|---|---|
| Single-Channel Power Supply | R&S®NGM201 | 3638.4472.02 |
| Dual-Channel Power Supply | R&S®NGM202 | 3638.4472.03 |
| Battery simulation | R&S®NGM-K106 | 3636.6626.02 |

# 7 Bibliography

[1] R&S®, "R&S®NGL200/NGM200 Power Supply Series User Manual," Rohde & Schwarz, 2021.

[2] <Autor>, "<Title> (Enter bibliography via >References >Manage Sources >Edit. In dialog, activate "Show All Bibliography Fields" to enter hyperlinks)," <Year>.

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