Report

Results report for the project MoMeWEC

NFR project N. 284231

Author(s):

Giuseppe Guidi

Report No:

2022:00124 - Unrestricted

Client(s)

The Research Council of Norway

SINTEF Energy Research
Postal address:
Postboks 4761 Torgarden
7465 Trondheim, Norway
Switchboard: +47 45456000
energy.research@sintef.no
Enterprise /VAT No:
NO 939 350 675 MVA

Report

Results report for the project MoMeWEC

NFR project N. 284231

KEYWORDS
EV charging
Modular converter
Wireless charging
Parking management

VERSION
1.0

DATE
2022-01-19

AUTHOR(S)
Giuseppe Guidi

CLIENT(S)
NFR

CLIENT'S REFERENCE
-

PROJECT NO.
502001941

NO. OF PAGES/ APPENDICES 7

SUMMARY
This report summarizes the results achieved during the whole period of project activities. The document is intended for upload into the NFR reporting website and is therefore organized according to the NFR guidelines.

PREPARED BY
Giuseppe Guidi

SIGNATURE

CHECKED BY
Jon Are Suul

SIGNATURE
Jon Are Suul (Jan 28, 2022 09:51 GMT+1)

APPROVED BY
Knut Samdal

SIGNATURE
Knut Samdal (Jan 28, 2022 10:14 GMT+1)

REPORT NO. 2022:00124
ISBN 978-82-14-07538-0
CLASSIFICATION Unrestricted
CLASSIFICATION THIS PAGE Unrestricted

Document history

VERSION	DATE	VERSION DESCRIPTION
1.0	2022-01-19	Submitted version

Table of contents

APPENDICES

Klikk eller trykk her for å skrive inn tekst.

1 Project objectives and background

The project MoMeWEC (Modular Megawatt-range Wireless EV Charging Infrastructure Providing Smart Grid Services, NFR project N. 284231) is an EU-Japan research cooperation project that has been funded under the umbrella of CONCERT-Japan. The project consortium thus includes both European and Japanese partners as follows:

- SINTEF Energi AS, Norway (project leader)
- The University of Tokyo (UTokyo), Japan (co-project leader for the Japanese side)
- RWTH Aachen, Germany
- Nagaoka University of Technology (NagaokaUT), Japan.

The underlying project idea stems from the observation that the rapid adoption of battery-equipped vehicles that we are witnessing worldwide is putting significant pressure on charging infrastructure. Improved methods for both design and management of ubiquitous high-power charging points are thus required to keep up with the ever-increasing number of vehicles and their bigger and more powerful on-board batteries.

Given this scenario, the project focuses on developing innovative solutions for high-power charging stations with minimum footprint and maximum flexibility that are therefore suitable for situations where space and power availability constraints are particularly stringent.
The **main objective** of the project is to combine the latest advances in power electronics, inductive power transfer and V2G/V2H concepts into a solution for multi-megawatt EV charging stations, resulting in reduced footprint, much lighter cabling and possibly the complete elimination of the transformer stage. Reduction of installation costs by about 20% compared to conventional charging station design is set as target.
Specific objectives stated in the project application are to:

- Assess the technical feasibility and the economic benefits of the concept.
- Develop a modular, distributed converter topology suitable for charging multiple vehicles independently with integrated wireless charging interface.
- Implement and optimize algorithms for distributed and coordinated battery charging.
- Equip the grid interface with suitable control algorithms for ensuring grid-friendly behaviour and seamless integration of V2G and V2H services.
- Share know-how between the partners by scheduling regular meetings and organizing four project workshops.
- Produce joint publications; at least one joint publication per year on peer-reviewed international conferences, plus at least two joint publications in peer-reviewed journals. All project members should participate in at least one joint publication.
- Facilitate researchers' and students' mobility; at least one researcher from each organization should visit a partner for a short-to-medium term stay every year.

A large share of the project activities is devoted to fostering international collaboration, as can be seen from the last three items in the list above.

2 Project results

The project has successfully achieved all the intended objectives, both in terms of scientific outcome and in terms of strengthened international cooperation, in spite of the difficulties related to the pandemic that has impeded international travel for a good part of the last two years.

The high-power, **multi-car parking-and-charging concept** based on modular converter design has been investigated thoroughly and several advances have been made on the power sharing techniques for such

kind of topologies that have been published by the MoMeWEC working group in renowned international scientific journals. The potential savings associated to the proposed topology have been quantified, showing that indeed the cost associated to medium-voltage transformers can be eliminated, while the amount of copper required for cabling within the infrastructure can be reduced by up to 93%.

Algorithms for optimized EV charging management taking into account the topology of the charging station has also been developed and salient results have been published.
Besides analytical and simulation results, a complete reduced-scale model of the electrical system associated to the parking infrastructure, from the connection to the three phase ac grid to the on-board battery of the vehicles has been realized in The National Smart Grid Laboratory at NTNU/SINTEF.

In total, nine **peer-reviewed joint publications** have been produced within the project, of which three have been published in renowned journals. Several other publications have been produced by the partners independently, using at least partially the results produced within the project, that has therefore been acknowledged. One more article in an IEEE journal is undergoing the second round of revision and is expected to be published after the project completion.

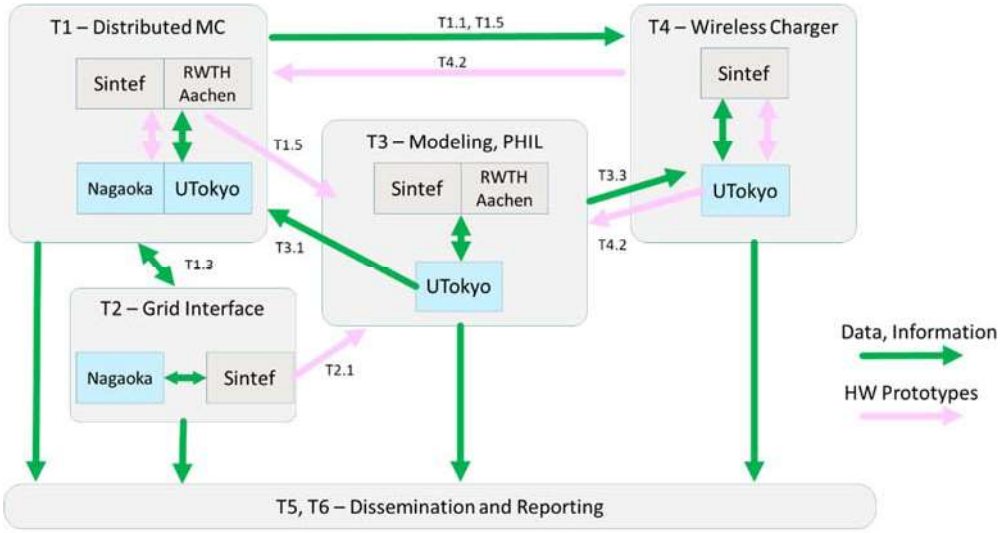
Besides the regularly scheduled working meetings between partners, the project has organized one **workshop** in each year of activity:

- Year 1: Kick-off workshop, Niigata, Japan
- Year 2: Working workshop, Aachen, Germany
- Year 3: Open workshop in Tokyo, Japan (fully organized with several invited speakers, but cancelled due to Covid)
- Year 4: Final workshop, organized within the IEEE SmartgridComm conference, Aachen, Germany.

The project has generated remarkable exchange of information, as also witnessed by the achieved researchers' mobility. Fifteen long-term (two weeks or longer) research stays have been recorded during the project duration, in spite of the impossibility of travelling for the good part of the last two years of activity.

2.1 Implementation of research tasks

The project was organized around four main R&D tasks. In the figure below, the Tasks are shown, along with the main participants in each of the activity and with the interactions between different groups.



T1 – Distributed modular converter applied to big parking lots. This is the core task of the project, and as such all the four research groups have been involved to some extent. SINTEF has been in charge for most of the theoretical work on the operation of the distributed power conversion topology, with the active participation of Nagaoka UT and, to a minor extent, of the University of Tokyo. SINTEF laboratories also hosted the reduced-scale prototype and the related real-time control infrastructure that has been used to produce results throughout the project period. Junior students from NagaokaUT played a major role in the building of the prototype. RWTH Aachen was mostly involved in the part related to high level control of the charging system.
T2 – Grid interface. Algorithms for ensuring the power quality at the transformer-less interface between the medium-voltage ac distribution grid and the charging infrastructure were developed within this task by SINTEF and NagaokaUT. RWTH Aachen has contributed for the part related to Vehicle-to-grid (V2G) services, which is an activity that started towards the end of the project and is still ongoing. The groups in SINTEF and Aachen are trying to find cooperation opportunities to continue on such activities.
T3 – Numerical simulation and PHIL. RWTH Aachen has been leading the activity on real-time simulation of the whole charging facility, with emphasis on novel management techniques that take into account the physical layout of the charging station. SINTEF has contributed with the model of the electrical infrastructure developed in T1. The work has resulted in the latest joint publication in IEEE Access, where the real-time operation of the MoMeWEC concept is reported.
T4 – Wireless charging station design. The wireless charging units envisioned in the MoMeWEC concept were designed within this task by the joint work of UTokyo and SINTEF that have a long track record of cooperation in the subject. The work on wireless charging was not limited to the MoMeWEC concept and has resulted in the design and construction of several small-scale prototypes whose operation has been reported in joint publications.

3 International cooperation

The MoMeWEC project was funded under the EU-Japan cooperation program CONCERT-Japan and, as such, international cooperation was arguably the main focus of the project. A large portion of the budget has been devoted to activities related to scientific exchange, both in the form of actual researcher mobility and in joint research.
During the first two years of the project, when international traveling was possible without restrictions, SINTEF has hosted five students from Japanese Universities, two of which for as long as four months. Their practical contribution to the building of the MoMeWEC system has been remarkable, but even more notable has been the intense interaction between Norwegian and Japanese researchers that resulted from their stay and that made possible the establishment of very solid scientific links existing today between SINTEF and both University of Tokyo and Nagaoka University of Technology.
The establishment of those links, together with access to unique laboratory facilities and know-how in the field of wireless power transfer, has been the rationale behind the long-term research stays of SINTEF senior researchers in Japan during the MoMeWEC project. It is because of the nurturing of such relationship and of the intense cooperation that the links have resisted the two years of forced isolation caused by the Covid crisis.

In a similar fashion, the research cooperation between SINTEF and RWTH Aachen has been strengthened considerably during the project period. Synergies between the research being pursued in the two organisations have been discovered and exploited. We are currently in the process of defining new possibility for joint research and exchanges that extend beyond the duration of the MoMeWEC project.

4 Project impact

As the number of battery-driven vehicles is increasing, the problem related to the charging infrastructure is going to become more and more relevant. The global trend in both the academic and industrial community is to go towards ever more powerful charging units, in an attempt to tackle the problem of long charging times. MoMeWEC, on the other hand, has tried to find solutions to a different issue: give access to charging outlets to people living in large apartment buildings and in extremely crowded areas. The MoMeWEC concept, although far from a TRL needed for real-world deployment, constitute a first step in this new direction and as such can be valuable for future developments.

It is also worth mentioning that the findings related to the operation and power management of modular converter structures are applicable to many other fields (e.g. distributed PV systems, distributed energy storage systems) and are therefore valuable even if the MoMeWEC parking concept does not find widespread adoption. The same consideration applies to all the know-how that has been developed in the field of wireless power transfer.

The project has also contributed to the improvement of international cooperation between Norway-Japan-Germany, with the creation of long-lasting links. Bringing together different research communities with very diverse background and know-how is going to enrich the research environment of each individual country and pave the way to out-of-the-box thinking.

5 Dissemination and future plans

The project has mainly relied on scientific channels for the dissemination of findings. However, some of the concepts discussed within MoMeWEC are deemed valuable and close to market-ready especially for charging system operators. The parking management strategies, including the possibility of advanced grid services, are examples of elements that can raise the interest of industrial players. The strategy for SINTEF is to bring the results generated in research projects like MoMeWEC into more industry-oriented projects (KSPs or even IPNs) and propose them to interested stakeholders. This can lead to further projects for the improvement of the methods (elevate to higher TRL) or, in some cases, to direct market adoption.

In the case of MoMeWEC, the pandemic situation has put serious restriction on the researchers' mobility and in spite of our best effort, some of the experimental activities have been delayed, with the result of having several lines of research (and several planned publications) that need further action beyond the project duration. SINTEF is trying to find synergies with related projects to bring forward the ideas that are worth pursuing and at the same time is trying to promote those ideas to Norwegian industrial partners. At the time of reporting, the MoMeWEC concept is being further analysed within the KSP FuChar, run by the same group of researchers in SINTEF. The link to the research group in RWTH Aachen is also being exploited within the same project.