Solution to the transition of indirect connections in EV charging infrastructures for grid stability

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BACKGROUND I: The rapidly changing EV environments

Today, there are around 3 million electric vehicles (EVs) in the United States: the potential of the future of electric vehicle is growing fast. There will be approximately 35 million electric vehicles on the road in 2030. There are currently 130,000 charging stations for EVs in the United States; however, there will be 500,000 public charging stations installed by 2030 with the tremendous growth expected in EVs. The global EV charging stations market will have the value of around US$30 billion by 2023.

The United States government is doling out US$5 billion to states to build a nationwide network of highway public charging stations intended to encourage more people to buy EVs. The plan calls for installing up to 500,000 direct-current “fast chargers” along the nation’s most heavily traveled highways.

The government wants to set minimum standards to ensure the national network of charging stations to be EV user-friendly, reliable, and accessible. Guidelines for the national public charging network are as the following.

i) The charging stations should be installed along major highways that the Federal Highway Administration has designated as "Alternative Fuel Corridors.”
ii) They should be located no more than fifty miles apart, and within one mile from interstate exits.
iii) They should feature DC fast chargers, providing a minimum of 150 kilowatt hours (kWh) of power at a time.

BACKGROUND II: Current issues related to level 3 charging infrastructure

The need for more investment and time: The chapter 1 guidelines generally define the installation of level 3 charging infrastructure. However, there are substantial challenges with such installations.

i) Level 3 charging infrastructure is typically more costly and time consuming.
ii) A grid-connected level 3 charging infrastructure is significantly different to level 1 and 2 charging infra.
iii) Sufficient discussions between the construction and the local utility companies are required at the time of installation to resolve permits or restrictions.

Issues related to grid system: In addition to the interested government officials, automotive suppliers and all users of electric vehicle hope a level 3 charging infrastructure network to be built in an economic and timely manner. However, the potential impact of EV charging at level 3 charging infrastructures on the grid system and the power plants is overlooked by many.

When EV are connected to level 3 charging stations, the behavior of the level 3 charging station will alter according to the power converter operation through either rectification or applying inverter mode to the EV. Therefore, the EV recognizes the power converter as a nonlinear input source during the rectification mode.

Concurrently, the EV battery will actively contribute to the frequency variation/ disturbance of the power grid system if not controlled for. If the grid is persistently disturbed, the power flow between the grid and the EV battery cannot reliably provide fast charging conditions for the EV.

This problem does not only affect the power flow but also reduces the power factor and grid frequency at the power plant [1].

IMPLICATIONS:

The worst-case scenario includes complete failure of the grid system and the power plant unable to supply sufficient power to their designated areas, resulting in a blackout; such pitfall may occur when more than hundreds of level 3 charging stations are connected to a single Point of Common Coupling.

This will impose a tremendous problem on the grid stability due to fluctuation of frequency and reduction of the power factor at the Point of Common Coupling [1].

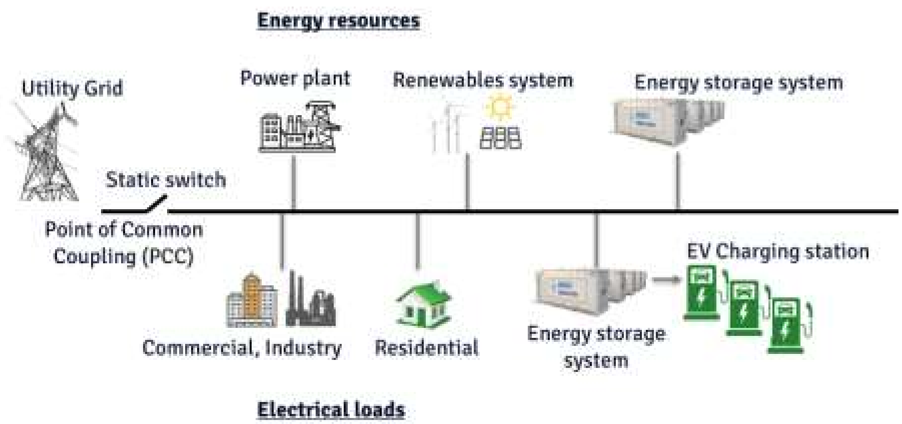

Fig. 1: Direct (active) connection to a single Point of Common Coupling

The general requirements for interconnection protection: i) over/under frequency protection; ii) over/under voltage protection; iii) sync check across the protective device before energizing; iv) overload and overcurrent protection in both directions.

[1] Ref. Electric Vehicle Charging Station: Cause and Solution to Grid System. IEEE Bulletin 2019.

INNOVATION: Introducing Our Novel Technology

Ever since the commercialization of electricity, there has been an untapped by-product in the form of magnetic fields generated by flowing currents in power lines. By harvesting and harnessing this unused, wasted magnetic energy, Ferraris has opened a new pathway for electric power generation and electrical energy recycling technology.

We developed the ERR system to allow for large-scale electrical energy production, as evidenced by a beta test that was successfully completed at a small hydroelectric power plant (Korea Midland Power). The beta test included evaluations on the integrity and reliability of the ERR system, and was assessed for 2.5 years upon installation. These favorable results were possible with our unprecedented, patented technologies (high-power ring cores manufacturing and power-focusing technologies).

The Energy Recycling Reservoir (ERR) system is designed to be a multipower-focusing module with contactless high-power ring cores that indirectly connect to power lines and generate electric power. The large-scale electrical energy produced can then either be stored in an Energy Storage system to be used when needed or distributed to the load in real-time.

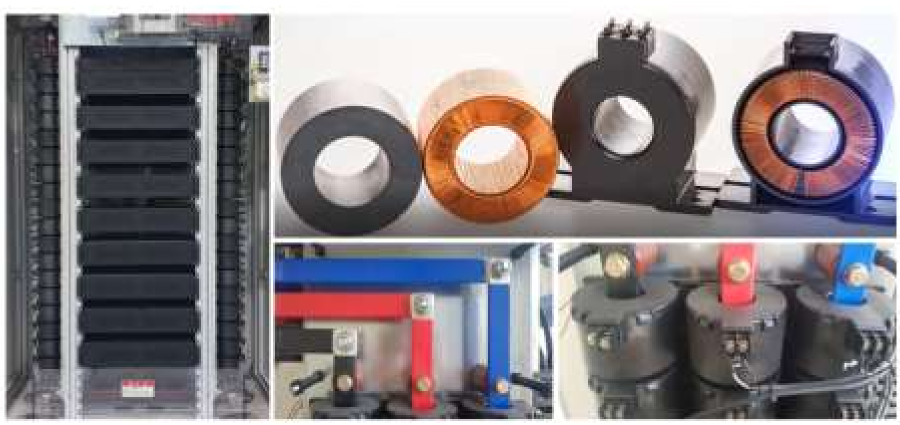

Fig. 2: The ERR system and its installation in a contactless method

The ERR system (models: UH-10 and UL-10) is typically installed in a contactless method on three-phase four-wire power lines (i.e., R, S, T, and N). The ERR system can be connected in cascade and/or parallel and is highly scalable for decentralized installations. The ERR system is operated in conjunction with its subsystem (Power Control system, Battery pack and, Monitoring system).

Additionally, if the ERR system is used for a load whereby reactive power occurs (kilovolt ampere reactive hours, kVArh), the system can reduce the reactive power by "Improved Power Factor Technology." With the ERR system, customers can thereby vastly improve the efficiency of power energy usage: for instance, by reducing the reactive power, improving the power factor, and more to ultimately save electricity.

However, the ERR system is not without limitations: if an outage occurs in a power line that is indirectly connected to the ERR system, the magnetism is lost and thus electricity would no longer be generated.

OUR APPROACH: New Pathway for EV charging infrastructures

The following outlines our potential strategic approach to address the aforementioned challenges by indirectly connecting the ERR system to the EV charging infrastructures, thus maintaining grid stability.

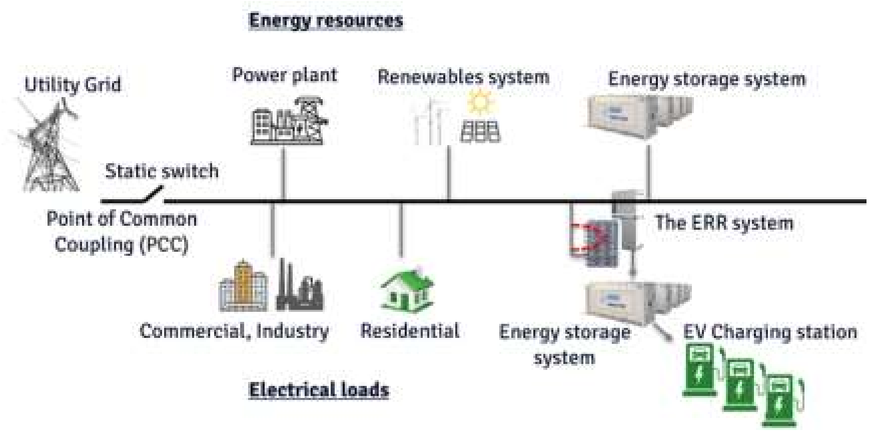

Fig. 3: Indirect (passive) connection to a single Point of Common Coupling

The biggest difference with the ERR system compared to the existing methods of EV charging stations and Energy Storage systems, which use electricity via direct (active) connections to the power line, is that the ERR system can minimize the impact on grid systems and power plants by eliminating frequency fluctuations and improving the power factor.