Sample Proposal for Electric Bus Inductive Charging Program
200 kW Proposal

Date: 26 August 2016
To: BYD Auto Co., Ltd. (BYD Coach & Bus)
Submitted by: Momentum Dynamics Corporation (Contractor)

Exhibit A – Scope of Work

Summary
Momentum Dynamics Corporation (Momentum or MD) is a Delaware corporation that has been engaged in the business of developing wireless (or inductive) charging technology for electric vehicles since 2009. The company is familiar with the specific requirements of this project as defined in the Request for Proposals.

In brief, this project will involve ______ fully electric BYD buses, which will have a single common inductive recharging location to be located at client’s primary facility.

It is understood that installation costs for the wireless power transmitter unit and any required electrical support infrastructure will be borne by client or other responsible agencies.

Momentum Dynamics will design and engineer, execute and deliver the following deliverables:

OBLIGATONS OF CONTRACTOR

Deliverables by Momentum Dynamics
Momentum will provide the following services and products:

1. **Vehicle Receivers and Vehicle Electronics:** _____ (_) vehicle power receiver units (sometimes referred to as “secondary” units), each unit to be identical and to include the following components:
   a. One Receiver for each bus, rated at 250 kW (200 kW delivered to battery).
   b. All integrated electronics necessary to provide DC power to the vehicle battery (does not include vehicle high voltage power DC power harness and connectors, which will be provided by BYD).
   c. Vehicle power and data interface electronics. The data interconnection will be bidirectional and is designed to take commands from the vehicle data bus and battery management system, as well as to monitor vehicle condition, enable and disable conditions, safe function, and power regulation.
   d. The onboard vehicle wireless near field communications system. This provides a secure and discrete connection between the charging bus and the off board transmitter. For a more detailed description, see Appendix A.
e. Connection ports to connect into the vehicle’s existing fluid cooling system. Ordinary ambient fluid cooling is used to remove heat from the onboard vehicle electronics.

2. **Transmitter:** ____ (__) Power Transmitters, rated at 200 kW, including the following components:

   a. A power transmitter embedded into the concrete pavement. (Ground preparation and finishing by others, Transmitter unit installation by MD)
      
      i. Required accessible power connection terminals designed for MD will supply this type of installation.

      ii. Transmitter will be engineered for repeated heavy wheel (bus) loading.

      iii. Transmitter will be designed to fit into the existing concrete pavement to a depth not to exceed the thickness of the existing concrete pavement (understood to be approximately 10"). *This embedment procedure is intended to save substantial expense by not requiring deep excavation or removal of subsurface foundation materials.* Installation will be limited to saw-cutting of existing pavement and removal of broken pavement (to be performed by others) within the region of the transmitter and, if required, conformal resurfacing of the pavement to ensure a clean and flush pavement surface, as well as joint sealing. *Note: The deep excavation and placement of a large precast concrete vault is not required.*

   iv. The new transmitter unit will be installed in such a manner as to ensure a safe and structurally sound pavement surface that will be compatible with the existing pavement. A licensed California state Professional Engineer will be providing construction drawings for permitting purposes to ensure the structural integrity and code compliance of this installation.

   v. The emplacement of code-compliant electric conduit either through trenching or through the use of a hydraulic rod pusher to minimize disturbance of the existing concrete curbs and walks (this work to be done by others but guided and facilitated by Momentum).

   vi. Permanent marking of the finished pavement above the transmitter to identify the transmitter location and promote the use of electric buses and inductive charging as a clean environment initiative.

3. **Power Electronics Panel:** ____ (__) independent Power Electronics Panel, to be provided and installed by MD.

   a. The power electronics Panel and Transmitter will be field certified by Underwriters Laboratory or an equivalent Nationally Recognized Testing Laboratory.

   b. The power electronics Panel and Transmitter will be provided with an appropriate license issued by the Federal Communications Commission (FCC).
c. The system operates automatically – driver actuation is not required. It turns itself on when a an authorized BYD bus is present and ready to charge and it turns itself off when the driver depresses the brake in expectation of placing the shift lever into drive.

d. The system turns itself off if a fault condition is encountered. The default condition is off. Multiple safeguards are designed into the system to prevent operation if an unsafe condition should arise.

e. The system works under all weather and temperature conditions. Power transfer through deep puddles of water, snow and ice are safe and do not result in a loss of efficiency.

f. The Power Electronics Panel is the connection point for the incoming power supply from the electric utility. Power from the utility is transformed from 480 volts AC, 3-phase, to direct current, and then converted to high frequency, and then filtered. This power conversion stage and all required electronics are contained entirely within the Momentum Dynamics Power Electronics Cabinet (NEMA-4 certified).

g. The Power Electronics Panel will be equipped with a power factor correction circuitry as required by the local utility.

h. The structural support for the Power Electronics Panel shall be as required by code and provided by the installation contractor. Permit drawings and the cost of installation of this concrete pad are not included in MD’s scope of products and services, however, MD will work diligently with the local engineer to provide requirements and specifications for the size of the support pad, its location, and conduit stub-ups.

i. If a separate disconnect switch, switchgear, junction box, or external energy meter is required by the property owner, local authorities, or by the utility company, this shall be the responsibility of client or other responsible authorities.

j. The Power Electronics Panel will be provided with an externally mounted status light to indicate functional states: 1) Charging, 2) Charging Complete, 3) System Fault.

k. Special power cabling to connect the Power Electronics Panel to the Pavement-Embedded Transmitter. Conduit to be specified by MD but supplied and installed by client or other authorities. MD will provide installation drawings and design specifications to project engineer to indicate position of conduit and will supervise installation.

l. Client or other authorities will supply and install buried conduit and power supply cable from power supply service to the Power Electronics Panel. MD will coordinate with and assist site designers, project engineer, property owner, code officials, and utility company to ensure least cost and most effective installation. Power Electronics Panel will be preconfigured to receive a code-compliant conduit connection at the panel entrance for the conduit and proper
electrical connections within the panel to ensure a safe and code compliant electrical installation.

4. Site Design Assistance and Partial Installation Services
   a. Momentum will work with client, the property owner, its assigned design engineers, and other officials to ensure a proper, safe and functional design. Momentum will provide design proposals showing preferred Transmitter and Power Electronics Panel locations; it is preferred that this be done using “as-built” site and electrical drawings in CAD format provided by the property owner or owner’s engineer.
   b. Momentum has on its staff a California state licensed Professional Engineer who will able to assist in coordinating the civil engineering aspects of this project.
   c. Momentum will provide a site installation team to install the Power Electronics Panel, the embedded Transmitter, and the associated high frequency cable that connects the Transmitter to the Power Electronics Panel.

5. Vehicle Adjunctive Equipment
   a. As part of Momentum’s vehicle integration, an LCD panel and annunciator will be provided at the operator location to assist in operating the inductive charging equipment.

6. Warranty
   a. The proposal provides for a warranty on parts and labor for three years.
   b. An extended warranty is available for years 4-12 at an additional annual cost.
   c. In both cases the warranty covers the vehicle inductive charging equipment (limited to Momentum’s charging equipment), and the ground-side Transmitter and Power Electronics Panel.

7. Commissioning, Training and Documentation
   a. Momentum will provide an Operational Manual to client.
   b. Momentum will provide on-site training for client operators and other personnel with an operational interest in the charging system and approved by client. This will be done at a time of convenience as scheduled by the parties.
   c. Momentum will also provide First Responder training to interested fire departments in the community. This training will be provided by Momentum and specifically be an electrical engineer who is also a volunteer firefighter.

8. Software/firmware updates
   a. This proposal includes software and firmware updates for 12 years with extended warranty.
9. Data Sharing

a. Momentum will be installing an Internet connection to the Power Electronics Panel. This is intended to allow secure remote monitoring of the performance of the inductive charging system. Additional functions allow Momentum to analyze any system issues or problems, improve system performance, perform predictive fault analysis, and log data regarding energy use and vehicle and charger performance.

b. This data may be useful in reporting to the public and to government agencies on the amount of pollution abated through the use of electric vehicles, and also to improve energy utilization. It may also be useful in helping utility companies plan for future electric vehicle installations.

c. Momentum is prepared to share this data with client as part of its installation. This data will be made available through a password-protected website available to client officials and others as may be designated.

10. Escrowed Data and Technical Information

a. Design documents including schematics and electronic diagrams, user manuals, software source code, and periodic software code upgrades, will be placed in escrow for a period of not less than twelve (12) years from the date of final acceptance of the installation and commissioning. Should Momentum Dynamics Corporation fail as a going concern and thereby become unable to service the installed equipment provided under this agreement, the above design documents will be released to client for the sole purpose of servicing equipment provided under this agreement. No other rights of any nature are conveyed by this provision. All copyrights and patents shall remain in force; all trade secrets shall remain confidential, and no attempt to reverse engineer, sell the information, or commercialize the technology will be permitted.

OBLIGATIONS OF OTHERS

BYD will provide the following products and services:

1. Provide _____ (_) fully electric buses.

2. Modify each of the ____ buses to receive the Momentum charging equipment. This will include modifications and adjustments (largely consistent with a DC off-board charger) in the following areas:

   a. Physical mounting of the Momentum receiver and the Momentum onboard electronics module. This may include placement of new brackets, bolt holes, and cable routing along the underframe of the vehicle, and within the rear electronics bay of the vehicle.

   b. Electrical power and data interconnections. This will include keeping the existing standard equipment plug-in charger but adding a new power interconnect for the power supplied from the inductive charger (thus making the vehicle chargeable by either plug-in or wireless systems). Harness wiring between Momentum's components will be provided by Momentum; harness
wiring from the Momentum equipment to the power and data interfaces with the BYD bus will be provided by BYD to ensure compatibility with BYD standards.

c. Coolant line connections. The Momentum onboard electronics module requires some cooling for its internal electronics. This is normally accomplished by connecting into the standard coolant lines that cool the vehicle’s motor controller and associated electronics. For this reason, mounting near the rear of the bus is preferred. Note that this is standard propylene glycol and water coolant, not an actively chilled coolant. Industry standard connection hardware will be used to make installation simple and continuing maintenance a standard operation.

d. Software and vehicle network integration. This is a matter of coordinating the vehicle’s CAN bus system, and the Battery Management System with the Momentum onboard electronics module.

3. The majority of vehicle integration activities, including physical mounting and testing prior to acceptance testing and shipment will be conducted at the BYD facility in Lancaster, CA. Momentum personnel will be present at the BYD facility for this activity and BYD agrees to cooperate with Momentum and allow necessary access to essential engineering data and to the fabrication facility.

**BYD or client will be responsible for the following items:**

1. Secure all government approvals, permits, variances, and easements necessary for Momentum to perform their services and for the other contractors responsible for other aspects of the work to complete their installation.

2. Schedule and arrange for all required code compliance inspections.

3. Coordinate the activity and any prerequisite or mandatory utility infrastructure improvements, and assume responsibility for completing this work. If this work will delay the schedule of installation, coordinate with all parties.

4. Obtain any required special permissions from the fire marshal.

5. Secure a certificate of completion, or equivalent, when the work is finished from the appropriate governmental agency (ies) or property authority.

6. Provide site engineering and properly sealed engineering drawings as required by law and for permitting. Momentum will actively cooperate in facilitating this design.

7. Set up and maintain a safe work zone during construction and obtain any required local, state, or federal required traffic control measures during the construction phase.

8. The necessary Categorical Exclusion (NEPA) for wayside improvements, for submittal to the Federal Transportation Administration.

9. Required installation procedures shall be described in detail based on a final determination of the Transmitter location and its proximity to the power supply. The
project engineer will determine the required procedure, a licensed professional
selected and provided by client and described in the construction documents. All
pavement saw cutting, rubble removal and disposal, pad base preparation, conduit
placement, handhole placement, backfilling and/or pavement repairs and sealing,
grading of landscaped areas and plant replacement, sidewalk protection and repairs if
needed, hydraulic ramming of conduit, trenching, power cable pulling, drilling and
placement of anchors, concrete dowels, epoxy-cemented pins, concrete reinforcement,
and related items, as MAY be described in the construction documents, will be the
responsibility of the primary installing contractor and shall not be the responsibility of
Momentum Dynamics. However, Momentum Dynamics will offer guidance and may
assist at its discretion in the installation process to ensure a safe and proper installation.
Project Managers

For Momentum:

- Project Manager: __________
- Government Affairs and Accounting: __________

Schedule

1. Momentum has taken the proactive step of planning for this project and will formally begin work as soon as it is notified by client and BYD of its selection as the Contractor.

2. It is recognized that a delay has been caused by circumstances preceding Momentum’s participation in this project. Nevertheless, Momentum is committed to effectuating the completion of a safe and fully functional – and properly tested – project as soon as practicable.

3. We anticipate completion of installation of the Transmitter Pad and Power Electronics Panel to take within 2-3 weeks, based on qualified installer.

4. We also anticipate vehicle integration be completed in approximately six (6) months. However, vehicle testing at the CA facility will require approximately 2-4 weeks. Acceptance of the vehicle, and shipment of the vehicle to client will establish the critical path delivery date.

5. The above dates are subject to possible delays caused by external factors, such as cooperation of permitting authorities and performance of the utility company.

Proposed Budget

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<th>Deliverable</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Extended Cost</th>
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<tr>
<td>200 kW Receiver &amp; onboard electronics</td>
<td>5</td>
<td>$ redacted</td>
<td>$ redacted</td>
</tr>
<tr>
<td>200 kW Transmitter &amp; Power Electronics Panel</td>
<td>5</td>
<td>$ redacted</td>
<td>$ redacted</td>
</tr>
<tr>
<td>Extended Warranty plus Extended Fleet Support for years 4-12 (_ Trans &amp; _ Receivers)</td>
<td>5</td>
<td>$ redacted</td>
<td>$ redacted Per Year</td>
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</table>

Extended warranty extends warranty on an annual basis.
Extended fleet support includes remote monitoring of system 24/7/365.

Service and support for years 4-12 are proposed to be billed annually.

Momentum reserves the right to make improvements to its technology and may propose and request permission of client to make improvements at no cost to client in the future. This may include software upgrades and hardware upgrades.
APPENDIX A

Momentum’s Wireless Near Field Communication System Description

Momentum has developed a critical technology that is necessary to safely operate wireless power vehicle charging. This is especially true for high power operations and where there are multiple charging transmitters and/or receivers. This system is patent pending and only available from Momentum Dynamics.

All wireless charging systems involve two components: a transmitter (or “primary” on the ground, and a receiver (or “secondary”) that is mounted on the vehicle. In order to operate effectively and safely, the two components must communicate with each other using a wireless data client. In this way power regulation, as controlled by the vehicle, can be communicated to the off-board transmitter that regulates charging power. Additionally, emergency shutdown commands can be rapidly communicated to the off-board system so as to stop charging immediately if this is required.

The communication system must be bidirectional to allow the off-board components to interrogate and determine the proper alignment and performance of the onboard components. Bidirectional data transmission also allows fast and routine software upgrades without interfering with or delaying the charging process.

The key features of this communication system are:

- The communication system must be “full-duplex” – meaning communications pass in both directions simultaneously.

- It must be discrete and have 100% assurance that there is no confusion between two or more nearby vehicles that are charging at the same time. Transmitter A, and only Transmitter A must receive the signal from Bus A. For example, a command to begin charging should not be “heard” by nearby chargers when there is no bus present over those chargers. Similarly, a signal to stop charging should not cause other charging buses to stop charging – the intended charger should only hear this command.

- The use of digital packet communications, or conventional radios, should be avoided. All digital radios (including Wi-Fi, Bluetooth, and others) are “half-duplex” (meaning communication can only pass in one direction at a time) and have long unpredictable signal delay periods (known as latency) of up to 50 milliseconds. More importantly, half-duplex systems have a tendency to be confused within their spectrum of operation with other devices, and can be “nulled” entirely (ie, signal is cancelled) by a phenomenon known as multipath. The system must have minimal signal latency limited to less than 4 milliseconds. Any longer and there is a risk of severe damage to the system when operating at high power.

- It must be able to pass the data signal reliably through water, ice, and snow – it must be unaffected by weather and environmental conditions.

- It should be highly secure, meaning that it should not be susceptible to easy spoofing by a malicious hacker.
Momentum has solved this problem with its patent pending Near Field Communication system. This system uses the near field properties of the magnetics that are used for power transfer to also transfer data. It meets all of the requirements listed above.
Subject: Technical Information Required for Proposal

A. Detailed technical specifications for optional in-route systems. This is to include engineering drawings, wire schematics, and Operations manuals.

Answer: See Attached Technical Sheet for 200 kW System.

B. Complete charging infrastructure installation plan. This shall include detailed timeline for the design, construction and acceptance of proposed charging stations at designated client facility.

The charging infrastructure includes two major component assemblies. The Vehicle Assembly is installed on and becomes part of the vehicle. This will be installed at the BYD factory and pretested at the factory. For the purposes of this response, the “infrastructure” will be regarded as the portion of the charging system that is installed off-board the vehicle, on the ground. We refer to this as the Ground Assembly.

The Ground Assembly involves two major parts, a pavement-embedded power transmitter, and a cabinet enclosure that contains the power electronics, control systems, and the grind interconnection. All of these components are manufactured in Malvern, PA USA and will be installed at the client site. There is one transmitter pad for each power cabinet and the power cabinet is typically located within 35 feet of the transmitter pads.
Any transmitter pad can recognize and charge any bus that is equipped with a Momentum charger Vehicle Assembly. Multiple buses can use any transmitter, though only one bus can be charged at a time. Typical on-route charging happens at a transit plaza or designated schedule make up stop location and is designed to provide enough energy to the vehicle battery in 5 to 10 minutes, sufficient to drive its next route and return to the travel plaza to repeat the process.

Installation of the Ground Assembly involves three stages:

1. Provide for a utility interconnection (“make ready”) by assuring there is adequate power available and upgrading the utility infrastructure as needed. Coordination between Momentum Dynamics, the utility company, the property owner, and the installing contractor, is essential. If the utility system requires an upgrade, this is usually performed by the utility company using their resources and contractors, and a separate fee may be charged. Momentum Dynamics is pleased to work with client to work with the utility company engineers to expedite this process and to reduce costs.

2. The Transmitter pads must be installed in the pavement and the power feed line conduits must be installed below grade. The high voltage of the system requires burial at a depth of 24” or greater with a concrete protective overcover. The transmitter pads are installed neatly by saw-cutting the existing pavement, removing the pavement material (just to a depth equal to the pavement), trenching to the required depth to install the power cable conduits, setting the transmitter pads in the shallow excavation created by removing the pavement rubble, supporting the transmitters with a proprietary scaffold-bridge support, and backfilling the excavation with new concrete. This locks the transmitters into place and assures that the heavy weight of rolling bus traffic can be supported. There are no serviceable parts in the solid-state transmitters, so there is no reason to remove them from the pavement during their useful lifetimes (20 years or more).

3. Provide an installation of the power electronics cabinet and the underground power feed lines that lead from the cabinet the pavement embedded transmitter pads. This must be done simultaneously with and coordinated with the utility company’s installation of its power feed cables below grade.

The installation sequence includes the following discrete steps:

1. Site Survey and existing utilities location.
2. Engineering site design.
3. Preparation of installation engineering drawings and bid package.
4. Contractor bidding for the installation of the Momentum Ground Assembly.
5. Concurrent coordination with the local utility to ensure adequate power, provide for any infrastructure upgrades, and coordinate installation of power lines to feed the Momentum power cabinets.
6. Acceptance of contractor bid and negotiation. Establish installation schedule. Variable that can affect this are weather and the availability of the electric utility and its installation timing, local permitting, and also the availability of the installing contractors.
7. Application for permits from local jurisdictions.
8. Delivery of equipment to site.
9. Contractor operations:
   a. Mobilization
b. Site layout
c. Site Protection.
d. Coordination with building officials for permit inspections.
e. Pavement cutting and trenching; removal of rubble.
f. Laying of conduit.
g. Setting shear dowels in the existing pavement to lock the new pavement to the newly poured concrete.
h. Installation of cabinet and fixation of conduit from the transmitter and from the utility feed.
i. Setting Transmitters with temporary scaffold-bridge support, including feeding high power lines through buried conduit to power cabinet.
j. Backfilling the void area around the transmitters with new concrete and finishing this new concrete to match the existing pavement. This includes any cut areas of the driveway, curbs and sidewalk areas.

The time required for field installation is approximately two weeks from the initiation of work.

The time required for all other activities that precede the site installation construction work is coordinated to happen concurrently with the fabrication of the charging units. Experience shows that the elapsed time from site survey to the letting of a construction contract depends most importantly on the local utility companies degree of responsiveness, and the permitting process. This can take two to three months and needs to be carefully project managed.

C. Supporting information about their proposed charging station.

The charging station, as described above, includes a neatly designed power electronics cabinet. This is the most visible part of the charging system. It is manufactured of stainless steel and meets NEMA 4 standards. It is deliberately designed to resist vandalism and the worst weather conditions.

The cabinet contains a ambient temperature fluid cooling system, very similar to what is used in vehicles. The only moving parts in this system, other than contact switches, are a pump motor and several small fans to move air over the enclosed heat exchangers.

The cabinet houses the equipment that takes 60 Hz 3-phase power from the utility and meters it, then rectifies and converts this power into 20 kHz alternating current. Power factor correction is integrated. It is this 20 kHz signal that is used to drive the resonating primary inductor in the road-embedded power transmitter. Additional functions include power regulation, safety interlocks, system control and monitoring, wireless communications with the vehicle using a proprietary near field communication technology, and date logging and reporting. A hard-wired or wireless data link to each power cabinet is provided to allow Momentum Dynamics to perform remote monitoring and data logging, and for the transit agency to monitor all charging functions.
200 kW Inductive Charging System for Municipal Electric Bus Applications

The Momentum® Dynamics wireless charging system provides a method of contactless power transfer based on near field magnetic induction between two charging disks. The system can provide up to 200 kW of power between a set of 4 disks while operating at frequencies of 20 kHz +/- 15%. The system is designed specifically for automatic on route charging of busses.

The system consists of a primary subsystem that includes a primary power module that converts power from the AC input and transfers the power through 4 primary charging disks through shielded cable.

The secondary subsystem consists of 4 secondary charging disks with attached secondary electronics modules and a secondary management module. The secondary electronics module is integrated onto the secondary disk and converts power into DC. The secondary management module contains power combining, charge control, and interface electronics for communications and control to the vehicle. An optional display can be included that provides alignment status and feedback to the driver of the vehicle. A basic block diagram is shown below.
Ground-Based Primary System
The primary power system consists of a Primary Power cabinet and primary disks to transmit the power to the secondary power system. Momentum Dynamics unique modular solution allows for a common design supporting from 60kW to 200kW charging.
**Bus-Based Vehicle System**

The secondary power system consists of a secondary disk to receive the power from the primary disk as well as secondary electronics and management modules mounted on the bus.

Momentum Dynamics offers an optional LCD screen to assist with alignment feedback and manual charging control. The optional alignment assist system provides feedback to the driver on when to stop the bus from moving forward as well as how well aligned the disks are for charging. Charging is automatically started and stopped based on the state of the bus. Charging can be optionally controlled through the LCD screen controls to start and stop charging, however, if the vehicle starts to move without pushing the stop button, the system will automatically detect the loss of load and shut down quickly and safely.
### Performance specification

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<th>Specification</th>
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<td>Voltage</td>
<td>400/480 V ac 3 phase</td>
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<td><strong>Input Current</strong></td>
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<td>Vehicle Unit Cooling</td>
<td>Ties into vehicle circulating coolant. No chiller required</td>
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<td>Ground Unit Cooling</td>
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Momentum Dynamics Corporation. Pioneering high power wireless charging solutions enabling rapid growth in electric vehicle adoption for a cleaner environment. Momentum Dynamics offers a portfolio of advanced wireless charging solutions across many vertical markets.

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