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SURFACE VEHICLE RECOMMENDED PRACTICE

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ENERGY TRANSFER SYSTEM FOR ELECTRIC VEHICLES—PART 1: FUNCTIONAL REQUIREMENTS AND SYSTEM ARCHITECTURES

Foreword—This SAE Recommended Practice is intended as a guide toward standard practice and is subject to change to keep pace with experience and technical advances.

The ability of Electric Vehicles (EVs) to correctly operate with the off-board electrical supply equipment used to charge them is a major concern for the producers and consumers of such vehicles. This concern stems from the cost of developing an electric "fueling" infrastructure. If EVs are to gain wide acceptance, this infrastructure must, at the least, provide consumers with the same level of convenience that is available for today's fossil-fueled vehicles. Ideally, there would be a single set of physical and functional requirements for the interaction between an EV and the off-board equipment. Designing to those requirements would allow any EV to charge with any off-board equipment, regardless of the producer of the vehicle or off-board equipment. This would be similar to today's internal combustion engine vehicles and gasoline pumps for unleaded fuels.

Today, there are two electrical energy coupling methods under consideration for EVs. One *conductively* transfers electrical energy (AC or DC) through metallic contacts. The other *inductively* transfers electrical energy through a separable transformer. These couplings are detailed in SAE J1772 and SAE J1773, respectively. Each of these physical coupling methods includes a means to communicate data that is necessary to control the transfer of energy to the vehicle. Unfortunately, these coupling methods are not physically compatible. Therefore, inoperability between EVs and equipment using different methods is not possible.

While inoperability between conductively and inductively coupled systems is not physically possible, each coupling method performs the same basic functions. When the combination of the EV and the off-board equipment is considered as a complete energy transfer system, there is no reason for the system's functional requirements to differ due to the physical coupling method. The only variation as a result of coupling method is the location (on-board or off-board) where specific functions are accomplished. Defining standards for certain functions of the total system and standards for the communication of data that pass between the EV and the off-board equipment will insure interoperability of equipment with common coupling methods. Different coupling methods will require a different system architecture, not different functional requirements.

Control of the charging of an EV's storage battery is specific to the type of battery and the configuration of the vehicle. Also, energy may be brought on-board a vehicle for purposes other than charging of the battery. These other purposes are specific to the needs of a particular vehicle. From these facts it follows that the EV should be in control of the transfer of energy from the off-board equipment. This way, EVs can have significantly different needs without forcing functional differences into the off-board equipment. It also establishes the EV (and its producer) as responsible to properly charge batteries, and allows charging requirements to evolve with developing battery technologies and EV experience.

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This document will define a set of functional requirements for an Energy Transfer System (ETS) for Electric Vehicles, independent of energy coupling method. It will also serve as an “umbrella” document by reference of other SAE documents written or modified to accommodate this application. It will define three different physical system architectures that correspond to:

a. Conductive AC coupling
b. Inductive coupling
c. Conductive DC coupling

Requirements will be included and detailed only to the level that will insure functional interoperability for systems with common physical architectures. When designing systems, there will be additional requirements to consider that do not affect interoperability and are not included here. If requirements are found that affect functional interoperablity, they should be considered for subsequent inclusion under the SAE J2293 umbrella.

This document has been jointly developed by the Electric Power Research Institute-National Electric Vehicle Infrastructure Working Council (EPRI-IWC), Charging Controls and Communication Committee and the SAE Electric Vehicle Charging Controls Task Force. The efforts of all who participated are greatly appreciated.

TABLE OF CONTENTS

1. ***Scope***—SAE J2293 establishes requirements for Electric Vehicles (EV) and the off-board Electric Vehicle Supply Equipment (EVSE) used to transfer electrical energy to an EV from an Electric Utility Power System (Utility) in North America. This document defines, either directly or by reference, all characteristics of the total EV Energy Transfer System (EV-ETS) necessary to insure the functional interoperability of an EV and EVSE of the same physical system architecture. The ETS, regardless of architecture, is responsible for the conversion of AC electrical energy into DC electrical energy that can be used to charge the Storage Battery of an EV, as shown in Figure 1.

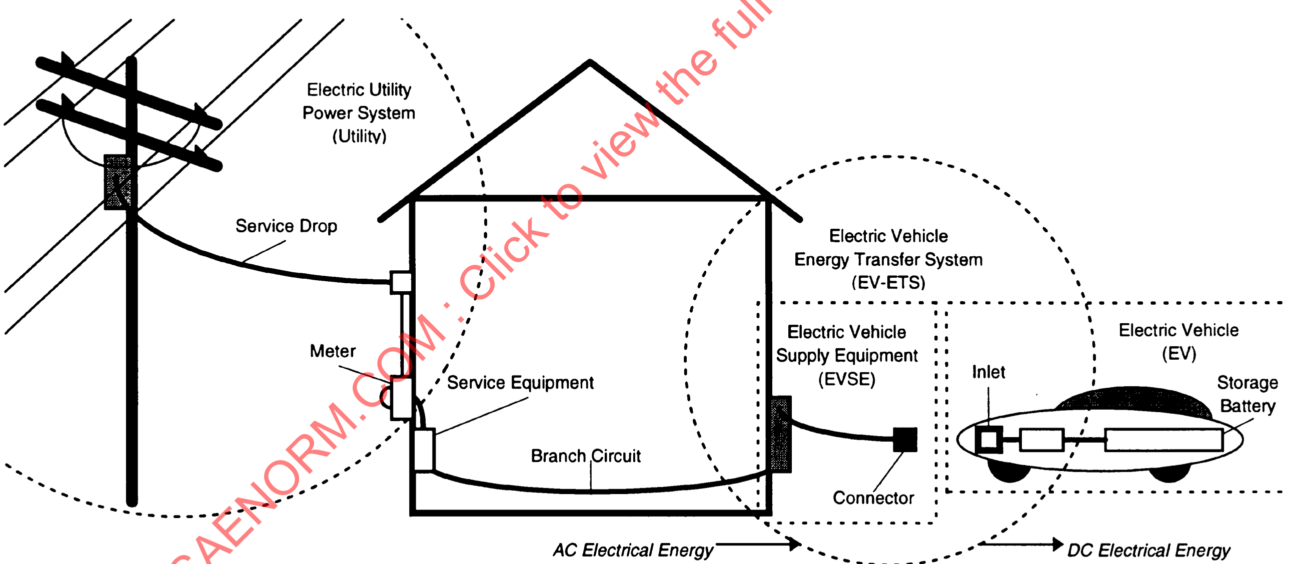

FIGURE 1—ELECTRIC VEHICLE ENERGY TRANSFER SYSTEM PHYSICAL CONTEXT

The different physical ETS system architectures are identified by the form of the energy that is transferred between the EV and the EVSE, as shown in Figure 2. It is possible for an EV and EVSE to support more than one architecture.

This document does not contain all requirements related to EV energy transfer, as there are many aspects of an EV and EVSE that do not affect their interoperability. Specifically, this document does not deal with the characteristics of the interface between the EVSE and the Utility, except to acknowledge the Utility as the source of energy to be transferred to the EV.

The functional requirements for the ETS are described using a functional decomposition method. This is where requirements are successively broken down into simpler requirements and the relationships between requirements are captured in a graphic form. The requirements are written as the transformation of inputs into outputs, resulting in a model of the total system.

Each lowest level requirement is then allocated to one of four functional groups (FG) shown in Figure 2. These groups illustrate the variations of the three different system architectures, as the functions they represent will be accomplished either on an EV or within the EVSE, depending on the architecture. Physical requirements for the channels used to transfer the power and communicate information between the EV and the EVSE are then defined as a function of architecture. System architecture variations are referred to as follows:

a. Type A—Conductive AC System Architecture—Section 7.2.1
b. Type B—Inductive System Architecture—Section 7.2.2
c. Type C—Conductive DC System Architecture—Section 7.2.3

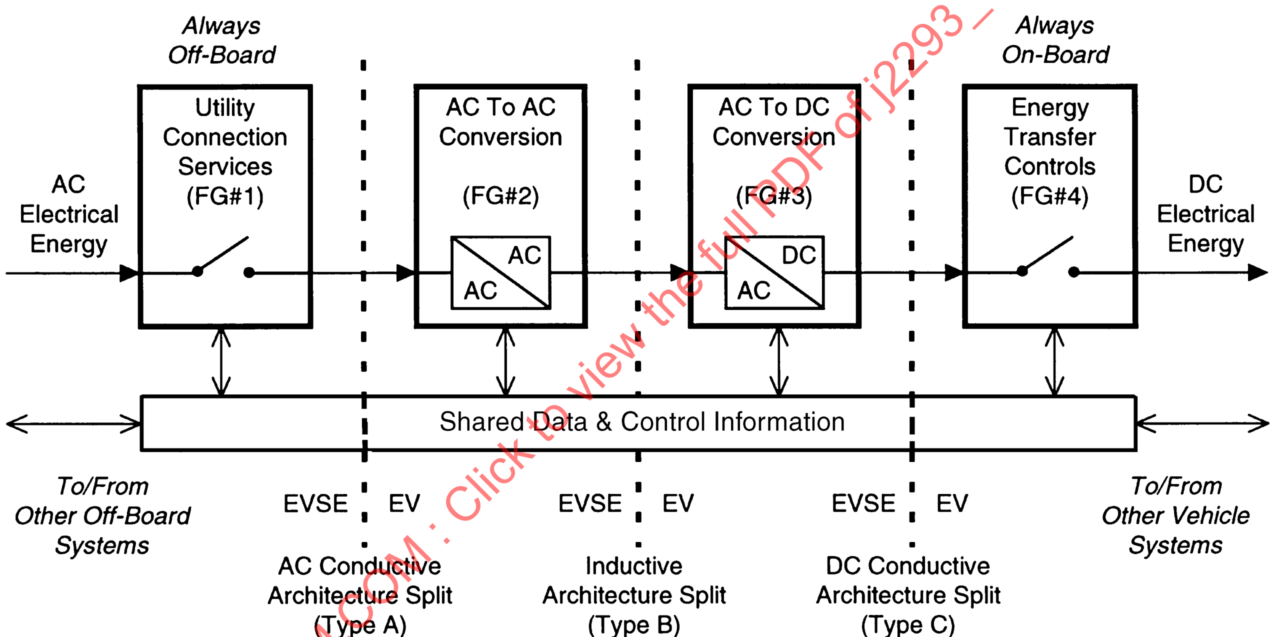

FIGURE 2—EV ETS FUNCTIONAL GROUP SERIES ENERGY CONVERSION

The requirements model in Section 6 is not intended to dictate a specific design or physical implementation, but rather to provide a functional description of the system's expected operational results. These results can be compared against the operation of any specific design. Validation against this document is only appropriate at the physical boundary between the EVSE and EV. See Section 8.

1.1 **Document Overview—**This document consists of two parts, as shown in Figure 3. Each part is published separately. Part 1 of SAE J2293 (Titled: Functional Requirements And System Architectures) describes the total EV-ETS and allocates requirements to the EV or EVSE for the various system architectures. It requires an SAE J1850-compliant network for communicating data and control information between an EV and EVSE.

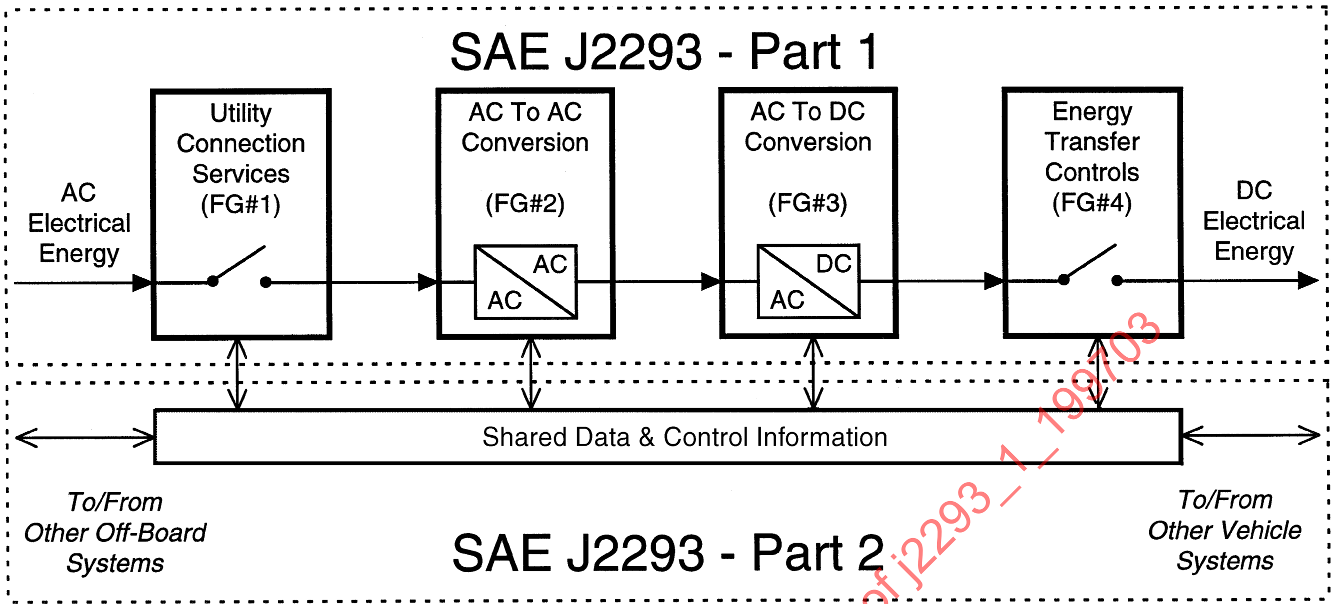

FIGURE 3—SAE J2293 PART 1 - PART 2 SPLIT

Part 2 of SAE J2293 (Titled: Communication Requirements And Network Architecture) describes the SAE J1850-compliant communication network between the EV and EVSE for this application (ETS Network). It treats the network as a system with the EV and EVSE from Part 1 as external elements using the network. Each part has the following outline:

Section 1 Scope—Defines the purpose and content of the document.

Section 2 References—Identifies the version and source of all other documents referenced within this document.

Section 3 Definitions—Defines terms that are specific to the subject of this document and are not defined in another reference.

Section 4 Abbreviations and Acronyms—Defines abbreviations and acronyms that are specific to the subject of this document and are not defined in another reference.

Section 5 System Definition and Context—Defines the purpose and content of the system by describing the relationship of the system to its environment (external elements). This section also defines specific constraints that will shape the functional and physical requirements.

Section 6 Functional System Requirements—Defines the specific requirements of the system using the functional decomposition method. The major functions are decomposed into simple, interrelated elements, without regard for whether a function will be implemented off-board or on-board the EV. These elements form a model of the total requirements.

Section 7 System Architecture—Defines the architecture(s) of the system. Each of the elements of the model in Section 6 are assigned to an EV or the EVSE. In Part 1, elements are first grouped into four functional groups. These groups form a series chain of energy conversations, as shown in Figure 2, that is representative of any of the ETS architectures.

Section 8 Validation—Identifies which of the requirements in Section 6 shall be validated for each of the architectures described in Section 7. Specific test procedures are defined as required.

Section 9 Data Dictionary—Defines each flow used as a part of the requirements model in Section 6. These are the minimum requirements that shall be considered when the system is actually implemented.

1.2 SAE Document Interrelationships—Figure 4 shows the interrelationships of SAE J1772, SAE J1773, SAE J1850, SAE J2178, and this document. SAE J2293 references these documents and provides additional information to form a complete set of requirements. There are other documents that will have an influence on the design of EV energy transfer system equipment. Where any conflicts exist in the following documents, the documents shall have the following order of precedence:

1. SAE J2293
2. SAE J2178
3. SAE J1850
4. SAE J1772
5. SAE J1773

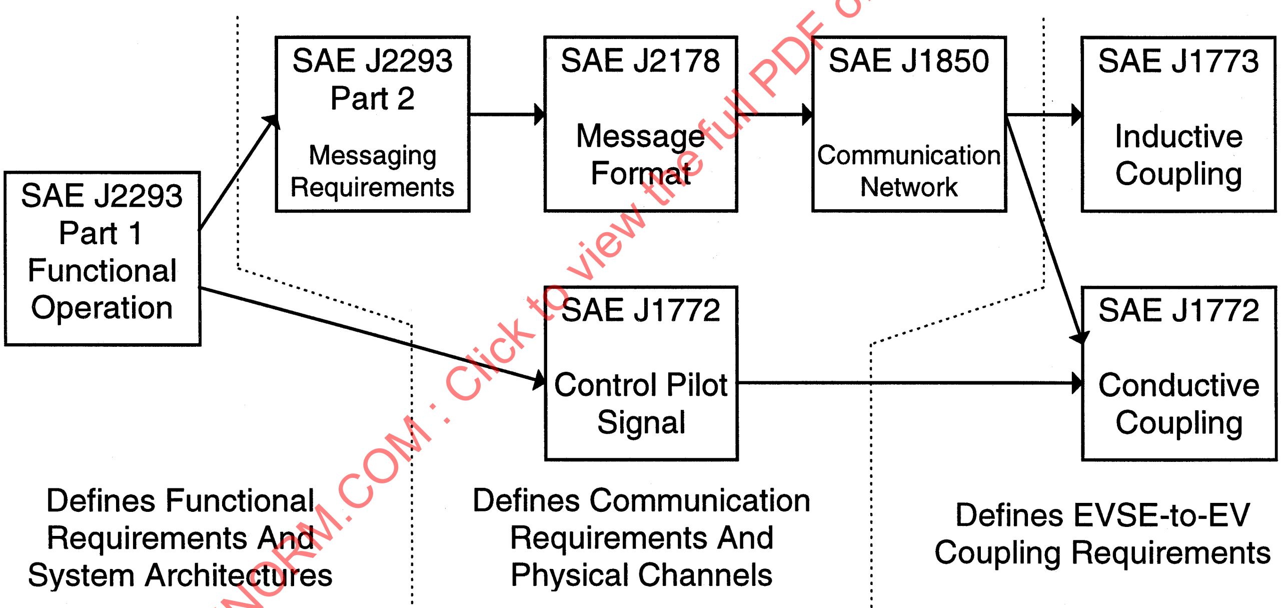

FIGURE 4—SAE J2293 DOCUMENT INTERRELATIONSHIP

1.3 System Classification—System architecture variations shall be referred to as the following:

a. Type A—Conductive AC System Architecture
b. Type B—Inductive System Architecture
c. Type C—Conductive DC System Architecture

Optional content for each system type is identified separately. See Section 7.

2. *References*

2.1 Applicable Publications—The following publications form a part of this document to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1715—Electric Vehicle Terminology
SAE J1772—Electric Vehicle Conductive Charge Coupling
SAE J1773—Electric Vehicle Inductive Charge Coupling
SAE J1798—Performance Rating of Electric Vehicle Battery Modules
SAE J1850—Class B Data Communication Network Interface
SAE J2178—Class B Data Communication Network Messages

2.1.2 ADDITIONAL REFERENCES—The following publications are mentioned herein and should be considered for reference.

2.1.2.1 *NFPA Publication*—Available from The National Fire Protection Association, Batterymarch Park, Quincy, MA 02269

NFPA-70-1996—National Electric Code (NEC)® - Article 625

2.1.2.2 *Other Publication*—Available from Dorset House Publishing, 353 West 12th Street, New York, NY 10014

Strategies For Real-Time System Specification - Derek J. Hatley and Imtiaz A. Pirbhai, 1988

3. *Definitions*

3.1 Battery—See Electric Vehicle Storage Battery.

3.2 Branch Circuit—The circuit conductors between the final overcurrent device protecting the circuit and the equipment supplied by the circuit. It is typically an unswitched circuit from the service equipment (fuse box) to an appliance. For this application, the appliance is the Electric Vehicle Supply Equipment (EVSE).

3.3 Control Flow—The representation of information, energy, or matter that is used to alter the behavior of a system. These are shown as dotted arrows on a data flow diagram (DFD) to indicate the source and destination of the flow. A flow may be both a data and a control flow, depending on how it is used by the system. This construct is used as a part of the functional decomposition process.

3.4 Control Specification (C-spec)—The description of a combinational or sequential logic operation, the results of which can be used as the input to a process specification (P-spec), or to describe when a process is to be operational. Types include decision tables (DT), state transition diagrams (STD), and process activation tables (PAT). C-specs are shown as a single vertical bar on a data flow diagram (DFD) and are referenced by the DFD level they appear on, followed by an s-index (e.g., 2.3.3-s1, 4-s7). This construct is used as a part of the Functional Decomposition process.

3.5 Data Flow—The representation of information, energy, or physical matter that is transformed by a system. These are shown as solid arrows on a Data Flow Diagram (DFD) to indicate the source and destination of the flow. A flow may be both a data and a control flow, depending on how it is used by the system. This construct is used as a part of the Functional Decomposition process.

3.6 Data Flow Diagram (DFD)—A diagram that shows the relationship between portions of a larger, more complex process as the process is decomposed. It captures the flow of data, energy, or physical matter between the portions. This construct is used as a part of the Functional Decomposition process.

3.7 Decision Table (DT)—A type of C-spec that defines the conditions required to determine the value of a combinational logic function. A combinational logic function, as opposed to a sequential logic function, is one where its present value (output) is dependent only on the present value of its arguments (inputs). See State Transition Diagram.

3.8 Electric Utility Power System (Utility)—The system that generates and delivers commercial electrical power to a residential or commercial building or facility. It extends to and includes a billing apparatus (electric meter).

3.9 Electric Utility/Local Load Management System (LMS)—A system that is responsible to monitor and control the load on some portion of the Utility or local premises' feeder and branch circuits. The goal of control may be to prevent overload or to reduce the cost of energy based on a specific billing agreement.

3.10 Electric Vehicle Storage Battery (Battery)—A group of electrochemical cells electrically connected in a series and/or parallel arrangement, the principal purpose of which is to provide DC electrical energy to propel the EV.

3.11 Electric Vehicle Supply Equipment (EVSE)—The equipment from the branch circuit to, and including, the connector that couples to the electric vehicle inlet, the purpose of which is to transfer electric energy to an EV. This equipment is located off-board the vehicle.

3.12 Elementary Process—A process in a data flow diagram (DFD) that is not decomposed further. Its function or activity is described by a process specification (P-spec). This construct is used as a part of the Functional Decomposition process.

3.13 Energy Transfer—The process of flowing energy to the EV from the EVSE.

3.14 Energy Transfer Strategy—A strategy that accounts for all of the electrical energy needs of an EV and the present status of all on-board equipment, including the EV Storage Battery. It determines the rate that energy is to be transferred to the EV and how the ETS shall be operated to accomplish this.

3.15 Energy Transfer System (ETS)—A system that is distributed between an Electric Vehicle (EV) and the off-board Electric Vehicle Supply Equipment (EVSE), the purpose of which is to transfer electrical energy from the Utility Power System (Utility) to the EV Storage Battery and other vehicle loads. The EV and EVSE must be connected together for energy to be transferred.

3.16 Functional Decomposition—A method used to describe the functional and behavioral requirements of a system, component, or device, captured as a model of the requirements. It involves the hierarchical break-down of complex requirements into simple, easy to describe pieces. The flow of information, energy, and matter between the pieces is captured, along with the process and control requirements.

3.17 Interoperability—The condition where components of a system, relative to each other, are able to work together to perform the intended operation of the total system. As an example, a 10-mm box-end hand wrench and a 10-mm socket wrench are interoperable, relative to a 10-mm hex-head bolt. The wrench and the bolt are both parts of a fastening system. The fact that the system will perform as required with either wrench establishes the interoperability of the wrenches and the bolt.

3.18 Off-Board/On-Board Boundary—The point where the ETS is divided into two physical parts. One part becomes realized within the off-board Electric Vehicle Supply Equipment (EVSE). The other part becomes realized within an Electric Vehicle. This boundary will be in different places, depending on the system architecture.

3.19 Power Stage—A physical and/or logical section of power conversion equipment that can provide conversion over a portion of the total conversion power range of the equipment. The range of a specific power stage will overlap with its adjacent stages.

3.20 Process—A function or activity that can be described as an input/output relationship or as the combination of simpler processes. A process is a basic building block of a data flow diagram (DFD).

3.21 Process Activation Table (PAT)—A type of C-spec that defines the exact conditions required for the indicated P-specs to be active. This construct is used as a part of the Functional Decomposition process.

3.22 Process Specification (P-spec)—The description of an elementary process. The description may include text, figures, and tables. The description captures the input/output relationship for all flows shown on its related data flow diagram (DFD). A P-spec is shown as a circle on a DFD, and has no further "child" processes below it. This construct is used as a part of the Functional Decomposition process.

3.23 State Transition Diagram (STD)—A type of C-spec that defines the exact conditions required to determine the value of a sequential logic function. A sequential logic function, as opposed to a combinational logic function, is one where its present value (output) is dependent on the present value of its arguments (inputs) and some number of the previous values of the arguments (previous inputs). See Decision Table.

3.24 Type A Architecture—A form of the ETS where AC electrical energy is transferred from the EVSE to the EV, across the off-board/on-board boundary, via a conductive coupling.

3.25 Type B Architecture—A form of the ETS where AC electrical energy is transferred from the EVSE to the EV, across the off-board/on-board boundary, via an inductive coupling.

3.26 Type C Architecture—A form of the ETS where DC electrical energy is transferred from the EVSE to the EV, across the off-board/on-board boundary, via a conductive coupling.

3.27 Utility—See Electric Utility Power System.

4. Abbreviations and Acronyms

C-spec	Control Specification
CSMA	Carrier Sense Multiple Access
DFD	Data Flow Diagram
DT	Decision Table
EPRI	Electric Power Research Institute
ETS	Energy Transfer System
EV	Electric Vehicle
EV-ETS	Electric Vehicle Energy Transfer System
EVSE	Electric Vehicle Supply Equipment
FG	Functional Group
FG#m	Functional Group m
HVAC	Heating, Ventilation, Air Conditioning
IWC	Infrastructure Working Council
LMS	Load Management System
NEC®	National Electric Code®

P-spec	Process Specification
PAT	Process Activation Table
SAE	Society of Automotive Engineers
STD	State Transition Diagram
VS	Ventilation System

5. ***System Definition and Context*****—**The EV Energy Transfer System (ETS), shown in Figures 1 and 2, converts AC electrical energy from the Utility into DC electrical energy for storage into an EV Storage Battery. The system includes functionality that will be implemented both on-board the EV, and off-board as a part of the Electric Vehicle Supply Equipment (EVSE). This system will not be partitioned into specific physical components. It will be described as groups of functions that are to be implemented as part of the EV or EVSE, depending on which of three different physical architectures is desired. The different system architectures: Conductive AC (Type A), Inductive (Type B), and Conductive DC (Type C), each perform the same system total function. The difference is that particular sub-functions will be performed either by the EV, or by the EVSE, depending on the architecture.

The ETS is defined to include all aspects of the conversion of AC electrical energy into DC electrical energy that will affect the functional interoperability of an EV and EVSE. This includes all aspects of the physical connection between an EV and EVSE such as communication signals and power forms.

5.1 External Interfaces—The ETS interacts with other functional systems that are not considered to be within ETS. This is illustrated in Figure 5. These interactions define the environment where the ETS must operate, and are the result of natural and mandated requirements. Some of these external systems are optional. Therefore, any particular ETS may or may not include an external interface to interact with them.

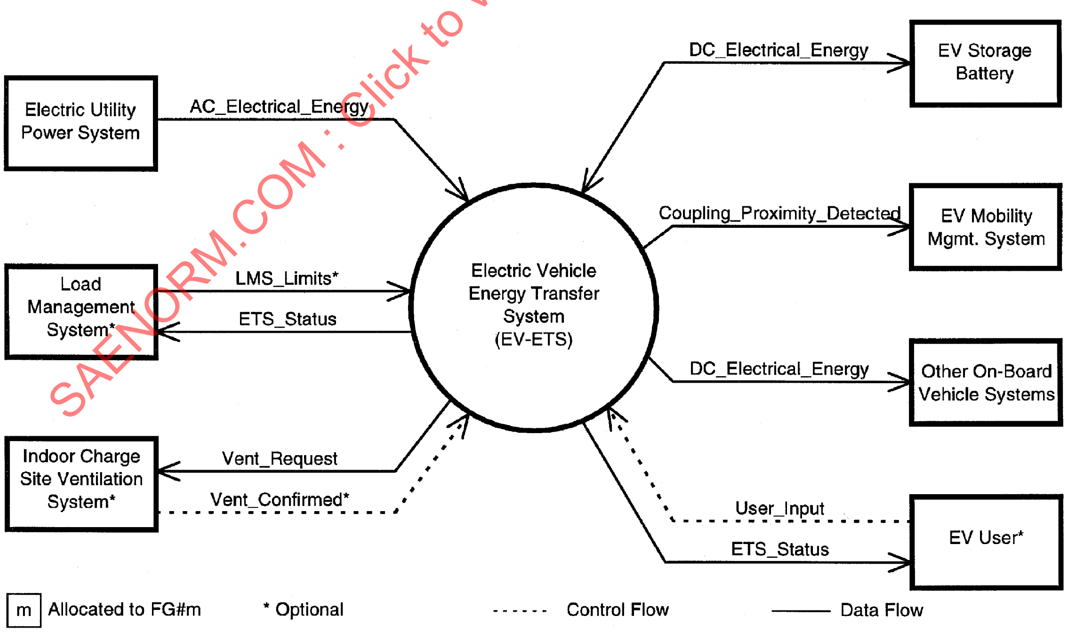

FIGURE 5—ELECTRIC VEHICLE ENERGY TRANSFER SYSTEM FUNCTIONAL CONTEXT DIAGRAM

The physical form of the external interfaces of ETS are not defined in this document. Their form will differ based on specific EV or EVSE physical designs.

5.1.1 ELECTRIC UTILITY POWER SYSTEM (UTILITY)—The Electric Utility Power System is responsible to provide common AC electrical energy. It is supplied via a branch circuit that is protected as required by national and local building codes for use with Electric Vehicles. The exact form of the AC electrical energy (i.e., voltage, frequency, etc.) is not of specific interest to the operation of the ETS. However, the ETS requires knowledge of the current rating of its branch circuit.

5.1.2 ELECTRIC UTILITY/LOCAL LOAD MANAGEMENT SYSTEM (LMS)—The Electric Utility/Local Load Management System (LMS) is an optional system that is responsible to manage the maximum load of the ETS on the Utility or the branch circuit.

An LMS will be located off-board the EV, because it is specific to the Utility or branch circuit. Therefore, LMS information will be brought into and out of ETS by way of the EVSE. It will then be communicated to the EV if necessary. EVSE may be designed with no accommodation for a connection to a LMS. When a connection is supported, the manufacturer of the EVSE shall define the physical characteristics of the connection to conform to the functional requirements defined in this document.

Some manufacturers of EVSE may choose to physically include LMS functions within their physical designs. For example, a “time of day” function that would allow the EVSE to transfer power only during off-peak rate periods could be incorporated into a specific EVSE design. However, this function would still be considered as outside the ETS’s functional scope.

When present, the LMS may establish preferred and mandated load limits that the ETS will not exceed. A preferred load limit may be ignored if the EV User takes action to do so. A mandated load limit may not be ignored. Also, the ETS will provide load status information back to the LMS. A single LMS may interact with multiple ETS installations.

5.1.3 INDOOR CHARGE SITE VENTILATION SYSTEM (VS)—The Indoor Charge Site Ventilation System (VS) is an optional system that is responsible to provide a specific level of ventilation for an enclosed (indoor) site where an EV is being charged. This system is optional because a specific EV model may be listed not to require it, per the National Electric Code (NEC®, NFPA-70-1996), Article 625.

A VS will be located off-board the EV, because it is specific to the charging site location. Therefore, VS information will be brought into and out of ETS by way of the EVSE. It will then be communicated to the EV if necessary. EVSE may be designed with no accommodation for a connection to a VS. When a connection is supported, the manufacturer of the EVSE shall define the physical characteristics of the connection to conform to the functional requirements defined in this document.

When present, the VS may be required to operate, and to confirm its operation, prior to and during energy transfer. Confirmation should be to detect that the electrical circuit which provides power directly to the ventilation device (fan) is energized. If VS operation is required and no VS is connected to the ETS, or confirmation of operation is not received, then energy transfer will not take place. See NEC®, Article 625 for further information.

5.1.4 EV STORAGE BATTERY—The EV Storage Battery is an electrochemical energy storage device that is responsible to provide DC electrical energy to operate an EV traction system and other vehicular systems. It shall be expected that the charging voltages of EV Storage Batteries will vary from 100 to 500 V with charging currents up to 400 A DC. The EV Storage Battery is replenished, or charged, when a voltage greater than the device’s open circuit voltage is applied to it.

5.1.5 EV MOBILITY MANAGEMENT SYSTEM (MMS)—The EV Mobility Management System (MMS) is the system or systems that is responsible to control the motion of the vehicle. This includes the propulsion, braking, and parking lock functions. In order to prevent damage to the coupling between the EVSE and EV, it is important that the vehicle be immobilized when a partial or full connection exists.

It shall be expected that the MMS will prevent the EV from moving relative to the EVSE when a connection between the two has been indicated by the ETS. This may be accomplished by whatever means the vehicle manufacturer determines is appropriate. When making the decision to immobilize the vehicle due to a connection, other factors should be considered. For example, if the vehicle is moving at 50 km/h and a connection becomes indicated, then it may be inappropriate to take an immobilizing action.

5.1.6 OTHER ON-BOARD VEHICLE SYSTEMS—Other On-Board Vehicle Systems includes other electrical loads on the vehicle that operate from the same DC electrical energy that is used to charge the EV Storage Battery. These loads may operate during energy transfer and are typically, but not limited to, HVAC and EV Storage Battery thermal management systems. It shall be expected that these loads may require a total of up to 5.0 kW of electrical power, and that any single load up to 3.0 kW may be switched on or off at any time.

The stated expectations are not intended to limit the electrical power used by other vehicle systems. However, these values were used during analysis to help define power stage overlap and power stage range values (see 6.3.1.2) that will prevent the switching of loads from exceeding the limits of a power stage.

5.1.7 EV USER—The EV User represents the human operator of the ETS. It serves as a source of certain information that may alter the operation of the system. It is also the destination for system status information that may be presented to the human operator.

The EV User may be located either off-board an EV while making a connection to EVSE, or on-board in the driver's seat. Therefore, EV User information will be brought into and out of the ETS by way of the EV and the EVSE. It can then be communicated to the other location if necessary.

The physical form of this interface will likely consist of operator input selectors and displays. The availability of EV User information is not intended to require an EV or EVSE to make the information available to the operator. The information that is actually presented to the operator, and the method with which it is presented, will likely be different for different EV and EVSE physical designs. Therefore, this interface can be considered to be optional.

5.2 Functional Content—The EV ETS is to provide the following three major functions as shown in Figure 6.

1. Switch and convert AC electrical energy into DC electrical energy, including accommodation for voltage controlled transfer.
2. Determine that the system is ready to properly transfer electrical energy from the Utility to the EV Storage Battery, including accommodation for an external VS.
3. Control the amount and rate of transfer of electrical energy to the EV Storage Battery, including accommodation for an external LMS.

Each of the three major functions will be decomposed into smaller portions. The data flows between these portions of ETS will be described to the level necessary to insure interoperability of an EV and EVSE of similar architecture.

The functions that could be included as a part of ETS are unlimited. The three previous functions are considered to be the minimum necessary to support the early development of an EV energy transfer infrastructure. As the EV marketplace continues to develop, additional functions will need to be added. Future additions have been considered as architecture decisions were made so that the additions can be made without making existing equipment obsolete.

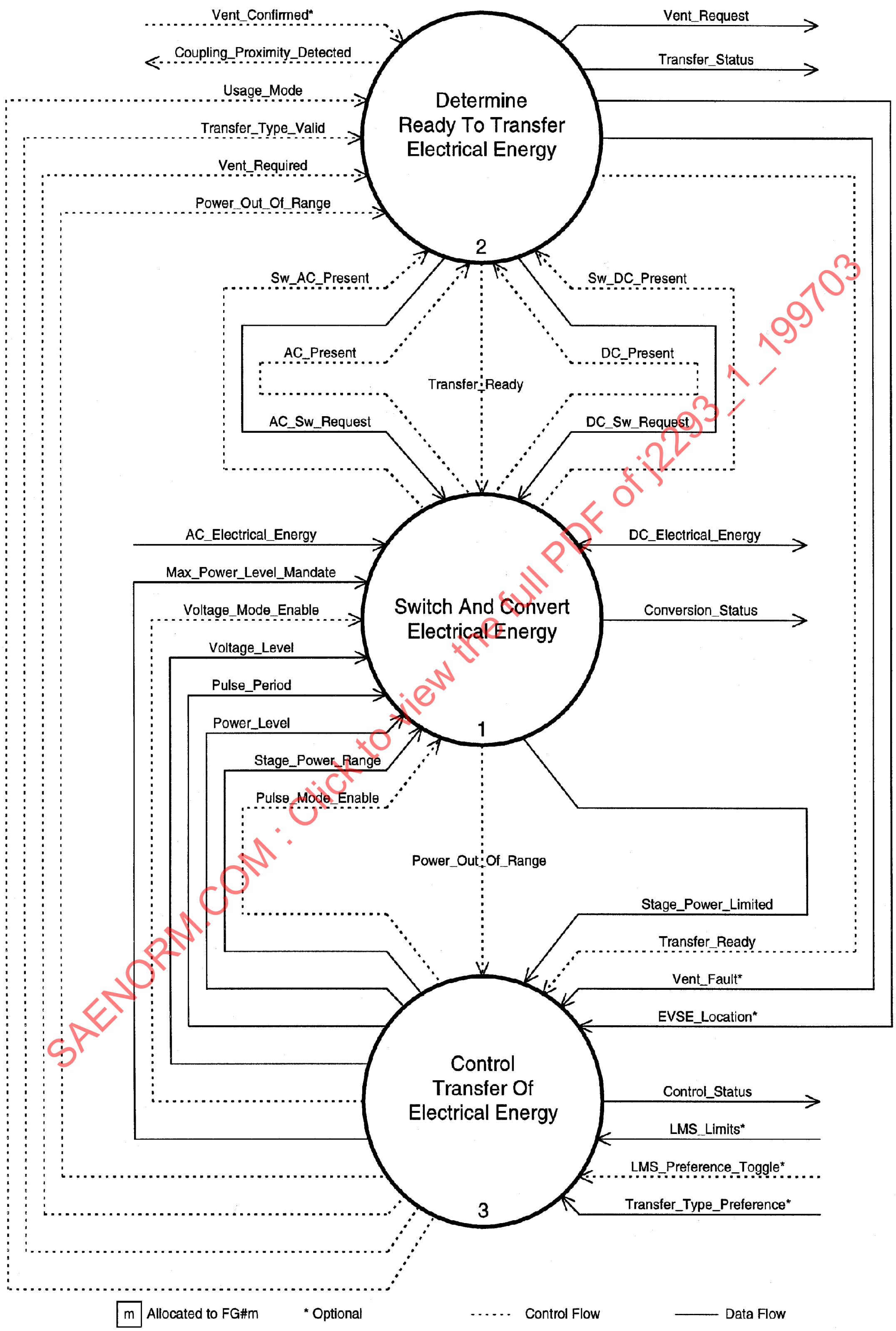

FIGURE 6—0.0: ELECTRIC VEHICLE ENERGY TRANSFER SYSTEM DFD

5.3 Functional Constraints—The ETS is based on the constraint that the EV must be in control of the energy transfer process. This is to say that the EV must control the voltage and current that is presented to the EV Storage Battery and to the Other On-board Vehicle Systems. Consider that the following items will be different for different EVs and that they will continue to evolve as EV designs mature:

a. Storage Battery's voltage and current requirements
b. Storage Battery-voltage distribution bus architecture

Since a Storage Battery is specific to an EV, it follows that the EV should control the process based on whatever parameters it sees fit.

The durability of the EV Storage battery must also be considered. The durability is a strong function of how it is charged. Therefore, it is important for vehicle manufacturers to control how the Storage Battery is treated in order to insure customer satisfaction and control warranty costs.

5.4 Physical Content—An ETS, regardless of architecture (Type A, B, or C), will be implemented in two parts: an EV and an off-board EVSE. There is no requirement for a specific physical design within an EV or EVSE. EV designs may distribute functions allocated to the EV to existing physical components within the EV.

5.5 Physical Constraints

5.5.1 EVSE - EV CONNECTION—The ETS is based on the physical coupling methods described in SAE J1772 and SAE J1773. These documents have been developed in parallel with this one to insure that these methods are capable of supporting the functional requirements of ETS.

5.5.2 EVSE - EV COMMUNICATION—SAE J1772 and SAE J1773 define an SAE J1850-compatible channel to provide a communication network between the EV and EVSE. This network is optional for a Type A system and shall be required for Type B and Type C systems. The usage of this network for the ETS application shall be considered "normal vehicle operation messages" as defined by SAE J1850, even though communication to an off-board device is required.

5.5.3 TYPE A AND TYPE C EVSE - EV CONNECTION DETECTION—The coupling method described in SAE J1772, in conjunction with the electrical requirements of the Control Pilot circuit, provides for the detection of an EVSE - EV connection by both the EV and EVSE. This is accomplished by transfer of the data items EVSE_Ready and Vehicle_Ready on this circuit. In order for the EV to detect a connection, the EVSE must first indicate that EVSE_Ready is "READY". See SAE J1772.

5.5.4 TYPE B EVSE - EV CONNECTION DETECTION—The coupling method described in SAE J1773 provides a dedicated switch for the direct detection of an EVSE - EV connection by the EV. However, the EVSE can only detect a connection by monitoring the SAE J1850 channel for activity from the EV. For a Type B architecture, the EV shall conduct some valid communication to the EVSE within 2.0 s of the coupler becoming fully seated in the inlet.

The connection detection problem is further complicated by a utility power outage and recovery situation while a Type B EVSE and EV are connected. If the outage is for anything but a short period, then the EV will likely go into a low-power stand-by (sleep) mode. When power recovers, the EV will remain inactive until some activity is present on the SAE J1850 channel. For a Type B architecture, the EVSE shall conduct some valid communication to the EV within 2.0 s of recovery from a utility power outage while the coupler is in the inlet.

It may not be cost effective for the EVSE to detect when the coupler is in the inlet while the vehicle is in stand-by, or to tell the difference between utility recovery and a typical "off" or "stand-by" to "on" transition. Therefore, the best solution may be to conduct some valid communication to wake the EV whenever the EVSE enters an "on" or operational state where energy transfer could occur.

5.5.5 NETWORK COMMUNICATION DELAY—SAE J1850 defines a Carrier Sense Multiple Access (CSMA) network with nondestructive contention resolution. This implies that access to the network (sending data) must be controlled in order to insure that all communication will be accomplished. The minimum interval between consecutive transmissions of any individual data/message for this application shall be 100 ms. All messaging shall be defined with this as a requirement. The maximum allowable latency for any communication required for normal operation shall be 2.5 times the expected time.

5.5.6 EV READINESS TO COMMUNICATE—SAE J1850 defines that nodes on a network may support a low-power standby (sleep) mode of operation where the node is capable of detecting network signal transitions for the purpose of returning to normal operation (wake-up). This is of particular interest when the power to operate a node is supplied by a battery, such as on an electric or motor vehicle. The EVSE and EV must always be able to communicate in order to support certain functions. Therefore, while connected together, the EV and EVSE shall maintain normal operation, or return to normal operation upon detection of network activity. See SAE J1850.

6. Functional System Requirements—The following are the functional requirements for the ETS. These describe what the system is supposed to do, within its defined environment. They do not define how these requirements are to be accomplished. These requirements are independent of any particular technology or system architecture.

A simplified form of functional decomposition will be used as a method to describe the requirements of the system. Requirements will be captured as related elements which have inputs and outputs that may represent information, energy, or matter. Each element transforms its inputs into outputs, thus capturing the requirements as a model of the system. Large, complex elements (parents) are broken down into a number of smaller, simpler elements (children). These elements are connected by flows that represent the information, energy or matter that passes between them. For detailed information on this method of system specification refer to Strategies for Real-Time System Specification, by Derek J. Hatley and Imtiaz A. Pirbhai (Dorset House Publishing)

The processes that describe ETS are shown in Figure 6. Each process will be decomposed to a level where it can be easily described. Also, an elementary process must be able to be totally realizable within an EV or EVSE for any of the three system architectures. This allocation will be shown in Section 7, by way of an intermediate architecture that consists of four functional groups. These groups will then be combined in three different ways that will represent the Type A, B, and C architectures.

6.1 Switch And Convert Electrical Energy—The purpose of this process is to convert AC electrical energy into DC electrical energy. It is decomposed as shown in Figure 7.

The process will describe each step of conversion as AC is transformed into DC. It also includes switching elements to insure that conductive connections for conductive architectures will make and break connection without electrical potential across the power contacts of the connection. See SAE J1772.

All portions of this process are active (producing output flows) whenever the total process is active. There is no explicit process activation control. However, for a process to provide an output flow, all inputs necessary to determine that flow must be available (data triggering).

6.1.1 DETECT AC PRESENT—The purpose of this process is to determine if the characteristics of AC_Electrical_Energy from the Electric Utility Power System are such that the ETS will operate properly.

The exact characteristics that should be considered when determining if AC_Electrical_Energy is appropriate for proper operation will vary as a function of a specific EVSE design and ETS architecture. Therefore, it is only practical to define general characteristics of AC_Electrical_Energy that can apply to any design or architecture.

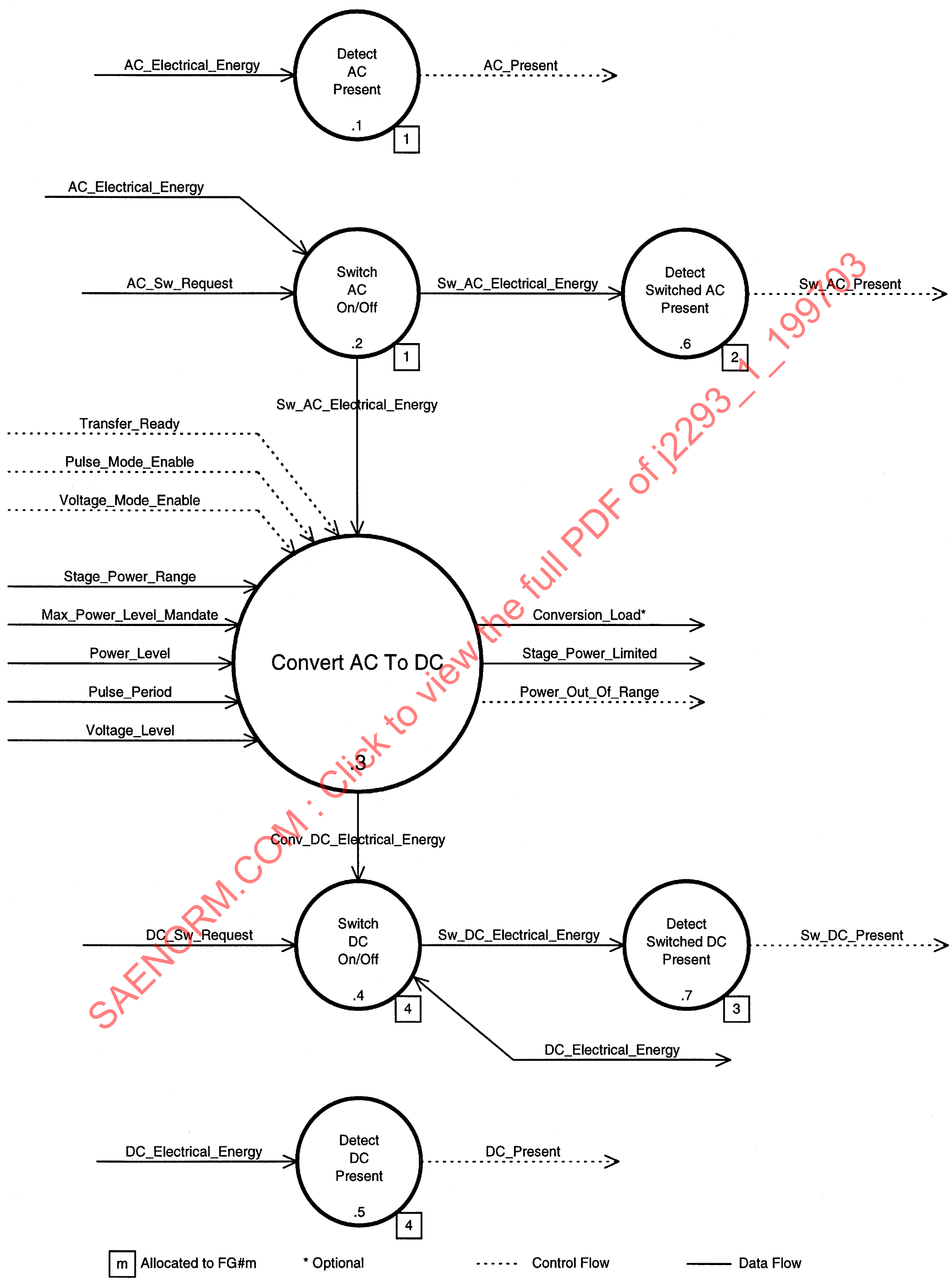

FIGURE 7—1.0: SWITCH AND CONVERT ELECTRICAL ENERGY DFD

6.1.1.1 Input/Output Flows—See Table 1.

**TABLE 1—DETECT AC PRESENT—
INPUT/OUTPUT FLOWS**

Flow Name	Type
AC_Electrical_Energy	Input
AC_Present	Output

6.1.1.2 Initialization—The following shall be performed once upon activation of this process:

AC_Present shall be assigned a value of "FALSE".

6.1.1.3 Operation—The following shall be performed continually while this process is active:

AC_Present shall be assigned a value of "TRUE" if the characteristics of AC_Electrical_Energy are such that the equipment to which this process is allocated shall operate properly, otherwise, it shall be assigned a value of "FALSE".

6.1.2 SWITCH AC ON/OFF—The purpose of this process is to provide on/off switching of AC_Electrical_Energy. The quality of the switch mechanism must be appropriate so that the equipment to which this process is allocated will operate properly. The exact characteristics that should be considered will vary as a function of a specific EVSE design and ETS architecture. Therefore, it is only practical to define general characteristics that can apply to any design or architecture.

6.1.2.1 Input/Output Flows—See Table 2.

**TABLE 2—SWITCH AC ON/OFF—
INPUT/OUTPUT FLOWS**

Flow Name	Type
AC_Electrical_Energy	Input
AC_Sw_Request	Input
Sw_AC_Electrical_Energy	Output

6.1.2.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.2.3 Operation—The following shall be performed continually while this process is active:

a. If the value of AC_Sw_Request is "CLOSED", then an electrical circuit between Sw_AC_Electrical_Energy and AC_Electrical_Energy shall be **closed** and stable within 750 ms.
b. If the value of AC_Sw_Request is not "CLOSED", then an electrical circuit between Sw_AC_Electrical_Energy and AC_Electrical_Energy shall be **opened** and stable within 250 ms.

6.1.3 CONVERT AC TO DC—The purpose of this process is to convert AC electrical energy in to DC electrical energy at a controlled level. Energy conversion will be limited to meet LMS and branch circuit load restrictions. The process is decomposed as shown in Figure 8.

This process accommodates the idea of distinct conversion power stages. It is expected that most equipment which offers a broad range of power conversion will do so in multiple stages with overlapping power ranges. However, it is acceptable to have a single stage. See 6.3.1.

Explicit activation of portions of this process shall be controlled as described in:

Table 3—1.3-s1: Conversion Mode PAT
Table 4—1.3-s2: Pulse Mode PAT
Table 5—1.3-s3: Voltage Mode PAT

However, for a process to produce an output flow, all input flows necessary to determine that flow must be available (data triggered).

TABLE 3—1.3-s1: CONVERSION MODE PAT

Transfer_Ready	1.3.1 Determine Conversion Load	1.3.2 Convert AC To AC	1.3.6 Convert AC To DC
"FALSE"	Disable	Disable	Disable
"TRUE"	Activate	Activate	Activate

TABLE 4—1.3-s2: PULSE MODE PAT

Pulse_Mode_Enable	1.3.3 Pass AC Power	1.3.4 Modulate AC Power
"FALSE"	Activate	Disable
"TRUE"	Disable	Activate

TABLE 5—1.3-s3: VOLTAGE MODE PAT

Voltage_Mode_Enable	1.3.5 Control DC Voltage
"FALSE"	Disable
"TRUE"	Activate

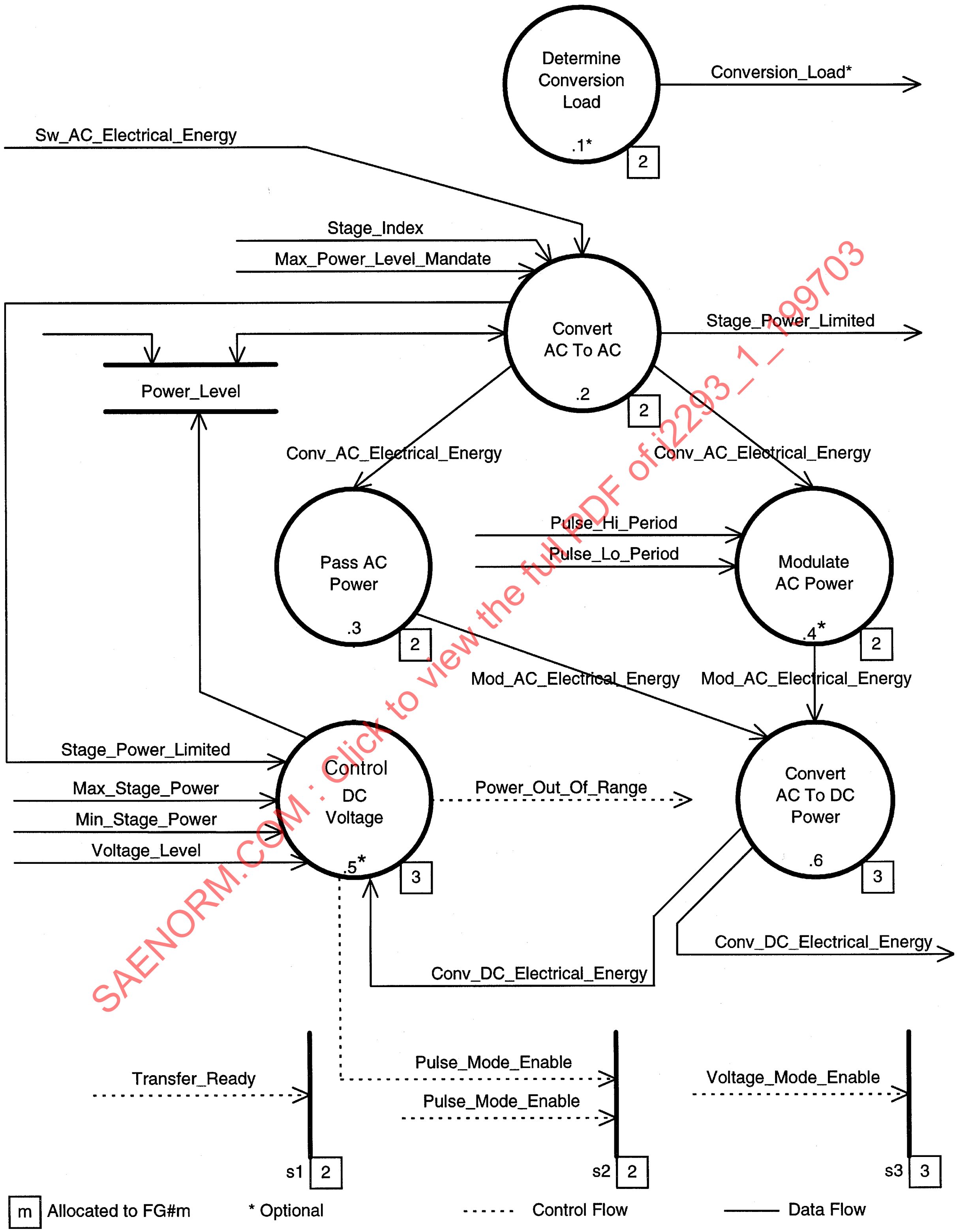

FIGURE 8—1.3: CONVERT AC TO DC DFD

6.1.3.1 *Determine Conversion Load (Optional)*—The purpose of this process is to determine the average current that is being drawn from the Utility to supply the ETS. This information is used by the optional LMS.

6.1.3.1.1 Input/Output Flows—See Table 6.

TABLE 6—DETERMINE CONVERSION LOAD—INPUT/OUTPUT FLOWS

Flow Name	Type
Conversion_Load	Output

6.1.3.1.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.3.1.3 Operation—The following shall be performed continually while this process is active:

a. Conversion_Load shall be assigned a value that represents the filtered average current of Sw_AC_Electrical_Energy with a first order lag time constant of 10 s. Conversion_Load shall have an accuracy of ±10% or ±2.0 A, whichever is greater, with respect to the actual current of Sw_AC_Electrical_Energy.
b. Conversion_Load shall increase (decrease) or remain the same as the average current of Sw_AC_Electrical_Energy increases (decreases).

6.1.3.2 *Convert AC-To-AC*—The purpose of this process is to provide the conversion of Sw_AC_Electrical_Energy into Conv_AC_Electrical_Energy at a controlled level. It is expected that most equipment will have limits imposed at times to prevent damage to itself. These self-protection power limitations are considered to be proper operation, and may be total or partial.

If this process is not active then no energy transfer is allowed, the same as for a Power_Level of zero.

The exact characteristics that should be considered when determining the self-protection limits of the equipment will vary based on a manufacturers' specific converter design. Therefore, no converter-specific flows are shown into this process.

The exact AC content of Conv_AC_Electrical_Energy is of particular interest for a Type B architecture due to the inductive coupling. See SAE J1773 for details.

6.1.3.2.1 Input/Output Flows—See Table 7.

TABLE 7—CONVERT AC-TO-AC—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Power_Level_Mandate	Input
Stage_Index	Input
Sw_AC_Electrical_Energy	Input
Power_Level	Input/Output
Conv_AC_Electrical_Energy	Output
Stage_Power_Limited	Output

6.1.3.2.2 Initialization—The following shall be performed once upon activation of this process:

Power_Level shall be assigned the value of 0 W.

6.1.3.2.3 Operation—The following shall be performed continually while this process is active.

6.1.3.2.3.1 Power Level—Power_Level shall be assigned the value of Max_Power_Level_Mandate, if the value of Power_Level is greater than Max_Power_Level_Mandate, otherwise, no value shall be assigned.

6.1.3.2.3.2 Converted AC Electrical Energy—The power of Conv_AC_Electrical_Energy is a function of the value of Power_Level and Stage_Index. The capabilities and limitations of the present power stage, indicated by Stage_Index, are identified in 6.3.1.2.

The following shall apply for values of Stage_Index from 1 to Max_Stage_Index, inclusive. The power of Conv_AC_Electrical_Energy shall be within the "Zero Power Operating Zone", as shown in Figure 9, for other values of Stage_Index, regardless of the value of Power_Level.

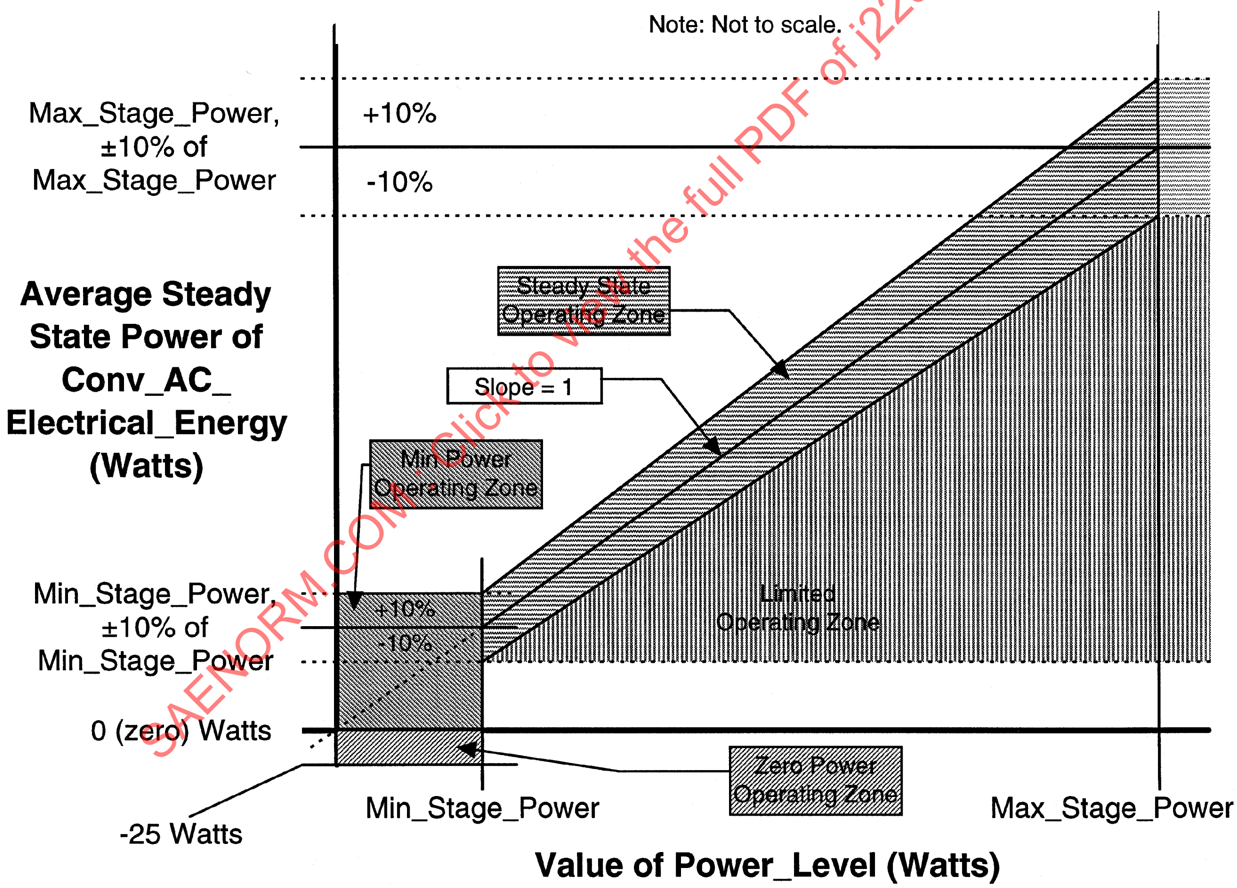

FIGURE 9—AC-TO-AC CONVERSION STEADY-STATE RESPONSE

a. Average Steady-State Power—The average steady-state power of Conv_AC_Electrical_Energy, as shown in Figure 9, shall be such that:

1. The power shall be within the “Steady-State Operating Zone” for any constant value of Power_Level greater than or equal to Min_Stage_Power and less than or equal to Max_Stage_Power.
2. The power shall be within the “Limited Operating Zone” for any constant value of Power_Level greater than or equal to Min_Stage_Power and less than or equal to Max_Stage_Power, if power within the “Steady-State Operating Zone” can not be achieved because the stage has a self-protection power limitation in effect.
3. The power shall be within the “Minimum Power Operating Zone” or the “Zero Power Operating Zone” for any constant value of Power_Level less than Min_Stage_Power and greater than 0 (zero). The power shall not alternate between zones once it has entered the “Zero Power Operating Zone”.
4. The power shall increase at a rate of less than 1500 W/s while within the “Limited Operating Zone” for a constant value of Power_Level as a self-protection power limit is relaxed.
5. The power shall be within the “Zero Power Operating Zone” for a constant value of Power_Level of 0 (zero).

The average power at any time shall be the average of the power for the succeeding 5.0 s.

b. Steady-State Power Stability—The power of Conv_AC_Electrical_Energy, as shown in Figure 10, shall be stable for any constant value of Power_Level such that:

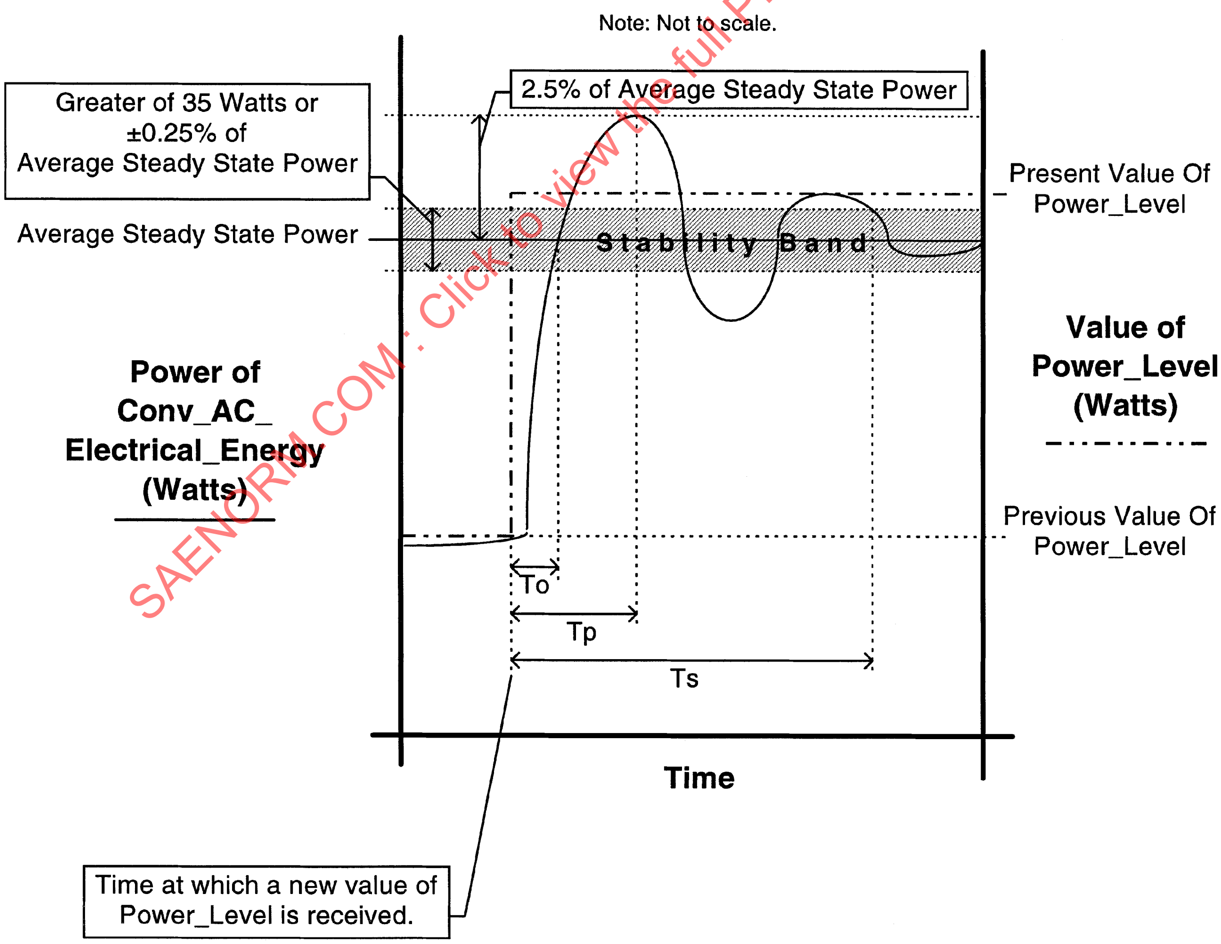

FIGURE 10—AC-TO-AC CONVERSION TRANSIENT RESPONSE

1. The instantaneous power shall remain within the greater of 35 W or ±0.25% of average steady-state power, centered on the average steady-state power.
2. The average steady-state power shall vary less than 100 W/s.

c. Time To Steady-State—The power level of Conv_AC_Electrical_Energy, as shown in Figure 10, shall be stable in time Ts for the indicated change in Power_Level, as described in Table 8. Ts shall begin when a new value of Power_Level is received.

TABLE 8—TIME TO STEADY-STATE

Previous Value Of Power_Level	Present Value of Power_Level is 0 (zero)	Present Value of Power_Level is Less Than the Previous Value of Power_Level	Present Value of Power_Level is Greater Than The Previous Value of Power_Level
0 (zero)	n/a	n/a	$Ts \leq \frac{\lvert \Delta Power\_Level \rvert (Watts)}{2,000(W/s)} + 1.5(s)$
> 0 (zero)	Ts≤ 0.10 (s)	$Ts \leq \frac{\lvert \Delta Power\_Level \rvert (Watts)}{10,000(W/s)}$	$Ts \leq \frac{\lvert \Delta Power\_Level \rvert (Watts)}{2,000(W/s)}$

d. Time To First Zero Error—The power level of Conv_AC_Electrical_Energy, as shown in Figure 10, may exceed the eventual average steady-state power in time To. There shall be no requirement for the period of time To.
e. Time To Maximum Overshoot/Undershoot—The power level of Conv_AC_Electrical_Energy, as shown in Figure 10, will reach peak power in time Tp. There shall be no requirement for the period of time Tp.
f. Maximum Overshoot/Undershoot—The power level of Conv_AC_Electrical_Energy, as shown in Figure 10, shall respond to a positive-going (negative-going) step in Power_Level such that:

1. The power shall not deviate from the eventual average steady-state power by more (less) than 2.5% of the average.
2. The power shall increase (decrease) monotonically until it reaches its maximum (minimum) level at time Tp.
3. The power shall deviate from the eventual average steady-state power by successfully smaller amounts through time Ts.

g. Maximum Relative Power Step—The value of ΔP shall be as defined in Table 9, based on the value of Max_Conversion_Power and Min_Stage_Power for the present Stage_Index.

The average power of Conv_AC_Electrical_Energy shall increase (decrease) by an amount less than twice any increase (decrease) in Power_Level greater than or equal to ΔP.

TABLE 9—MINIMUM CONVERSION POWER AND MAXIMUM STAGE POWER STEP

Max_Conversion_Power	Min_Conversion_Power	Maximum Stage Power Step (ΔP) When Min_Stage_Power ≤3.0 kW	Maximum Stage Power Step (ΔP) When Min_Stage_Power >3.0 kW
> 10.0 kW	≤3.0 kW	35 W	400 W
> 1.5 kW, ≤ 10.0 kW	≤180 W	35 W	400 W
≤1.5 kW	≤Max_Conversion_Power	1.5 kW	n/a

h. Maximum Absolute Power Step—The value of ΔP shall be as defined in Table 9, based on the value of Max_Conversion_Power and Min_Stage_Power for the present Stage_Index.

The average power of Conv_AC_Electrical_Energy shall remain constant or increase (decrease) by an amount less than or equal to ΔP for any increase (decrease) in Power_Level less than ΔP.

i. AC Content—The AC content of Conv_AC_Electrical_Energy shall be as required by SAE J1773.

6.1.3.2.3.3 Stage Power Limited—Stage_Power_Limited shall be assigned a value of "TRUE" if the average steady-state power of Conv_AC_Electrical_Energy is within the "Limited Operating Zone", as shown in Figure 9, otherwise, it shall be assigned the value of "FALSE".

6.1.3.3 Pass AC Power—The purpose of this process is to provide no modulation of the converted AC power.

6.1.3.3.1 Input/Output Flows—See Table 10.

TABLE 10—PASS AC POWER—INPUT/OUTPUT FLOWS

Flow Name	Type
Conv_AC_Electrical_Energy	Input
Mod_AC_Electrical_Energy	Output

6.1.3.3.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.3.3.3 Operation—The following shall be performed continually while this process is active:

The voltage, current, and AC content of Mod_AC_Electrical_Energy shall be the same as the voltage and current of Conv_AC_Electrical_Energy.

6.1.3.4 Modulate AC Power (Optional)—The purpose of this process is to provide on/off modulation of converted AC power, where the on and off periods can be controlled.

6.1.3.4.1 Input/Output Flows—See Table 11.

TABLE 11—MODULATE AC POWER—INPUT/OUTPUT FLOWS

Flow Name	Type
Conv_AC_Electrical_Energy	Input
Pulse_Hi_Period	Input
Pulse_Lo_Period	Input
Mod_AC_Electrical_Energy	Output

6.1.3.4.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.3.4.3 Operation—The following shall be performed continually while this process is active:

6.1.3.4.3.1 On/Off Modulation—The power level of Mod_AC_Electrical_Energy shall alternate between two levels, P0 and P1, as shown in Figure 11, such that:

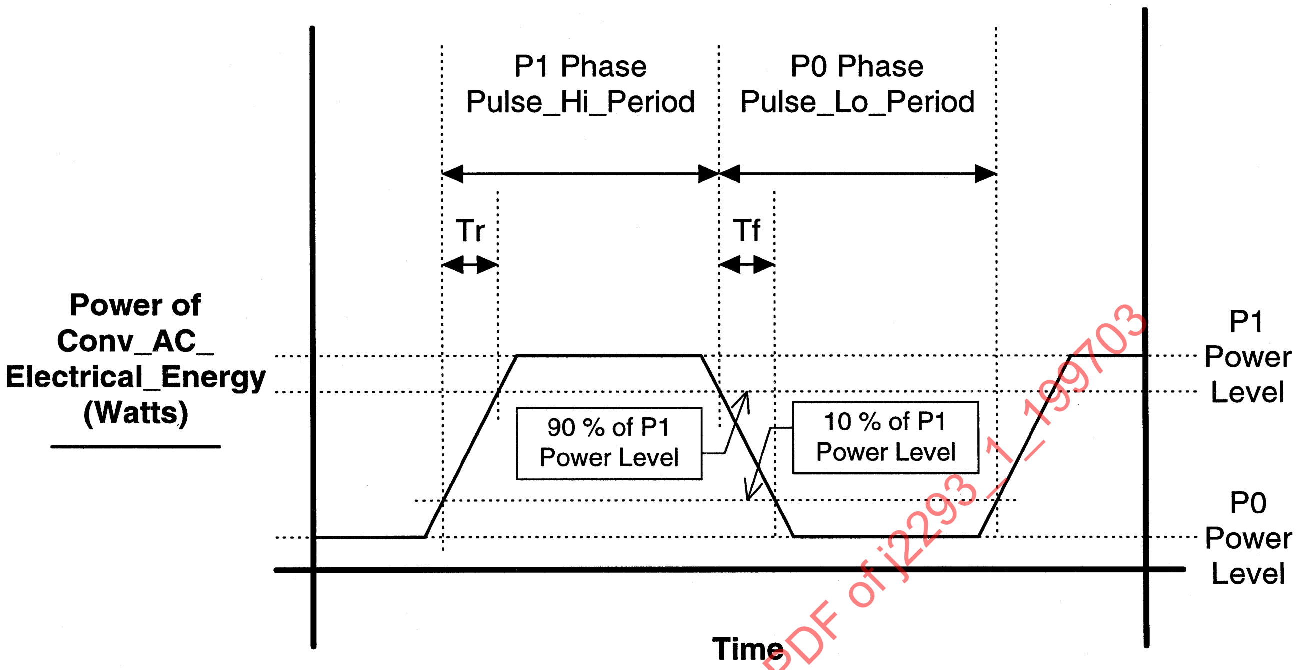

FIGURE 11—AC-TO-AC CONVERSION PULSE MODE TIMING

a. The P0 power level shall be greater than or equal to 0 W and less than 25 W.
b. The duration of the P0 power level shall be Pulse_Lo_Period. It shall range from 5 to 10 000 ms.
c. The P1 power level shall be the same as the power of Conv_AC_Electrical_Power.
d. The duration of the P1 power level shall be Pulse_Hi_Period. It shall range from 200 to 10 000 ms.
e. If the value of Pulse_Hi_Period or Pulse_Lo_Period is not within the ranges specified, then the P0 and P1 power levels shall both be the same as Conv_AC_Electrical_Energy.

6.1.3.4.3.2 Power Level Transition Time—The power level of Mod_AC_Electrical_Energy shall rise from 10% of P1 to 90% to P1 in the period Tr. Tr shall be less than 100 ms.

The power level of Mod_AC_Electrical_Energy shall fall from 90% of P1 to 10% of P1 in the period Tf. Tf shall be less than 5 ms.

6.1.3.4.3.3 Pulse Enable Time—The power level of Mod_AC_Electrical_Energy shall transition into the P0 power level for the first time within 500 ms after this process becomes active.

6.1.3.5 Control DC Voltage (Optional)—The purpose of this process is to provide closed-loop control of the AC-to-AC conversion in order to achieve a target DC voltage level. The power level of the conversion will be controlled into the EV Storage Battery and Other On-Board Vehicle System as the load (see 5.1). The exact control method will not be specified, except to describe the desired voltage control response. The target voltage, indicated by the value of Voltage_Level, can not change value while this process is active.

It is expected that some battery management strategies will require that the DC circuit to the battery be opened and energy transfer to the EV be continued to support the other loads. High power conversion stages may not be able to deliver lower power levels, requiring that a lower power stage be selected. In order to support this optional function, additional restrictions are placed on Min_Conversion_Power (see 6.1.3.5.3.2).

This process is not limited by recommended LMS limits (Max_Power_Level). However, required LMS limits (Max_Power_Level_Mandate) will be applied by other down-stream processes.

6.1.3.5.1 Input/Output Flows—See Table 12.

TABLE 12—CONVERT AC-TO-DC VOLTAGE INPUT/OUTPUT FLOWS

Flow Name	Type
Min_Stage_Power	Input
Max_Stage_Power	Input
Stage_Power_Limited	Input
Voltage_Level	Input
Conv_DC_Electrical_Energy	Input
Power_Level	Output
Power_Out-Of-Range	Output
Pulse_Mode_Enable	Output

6.1.3.5.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.3.5.3 Operation—The following shall be performed continually while this process is active:

6.1.3.5.3.1 Pulse_Mode_Enable—Pulse_Mode_Enable shall be assigned a value of "FALSE".

6.1.3.5.3.2 Power_Level—The voltage of Conv_DC_Electrical_Energy is a function of its power and the load it drives. A change in the load will result in a change in the voltage given constant power. Power_Level shall be assigned a value such that the voltage of Conv_DC_Electrical_Energy shall provide the following voltage response as shown in Figure 12.

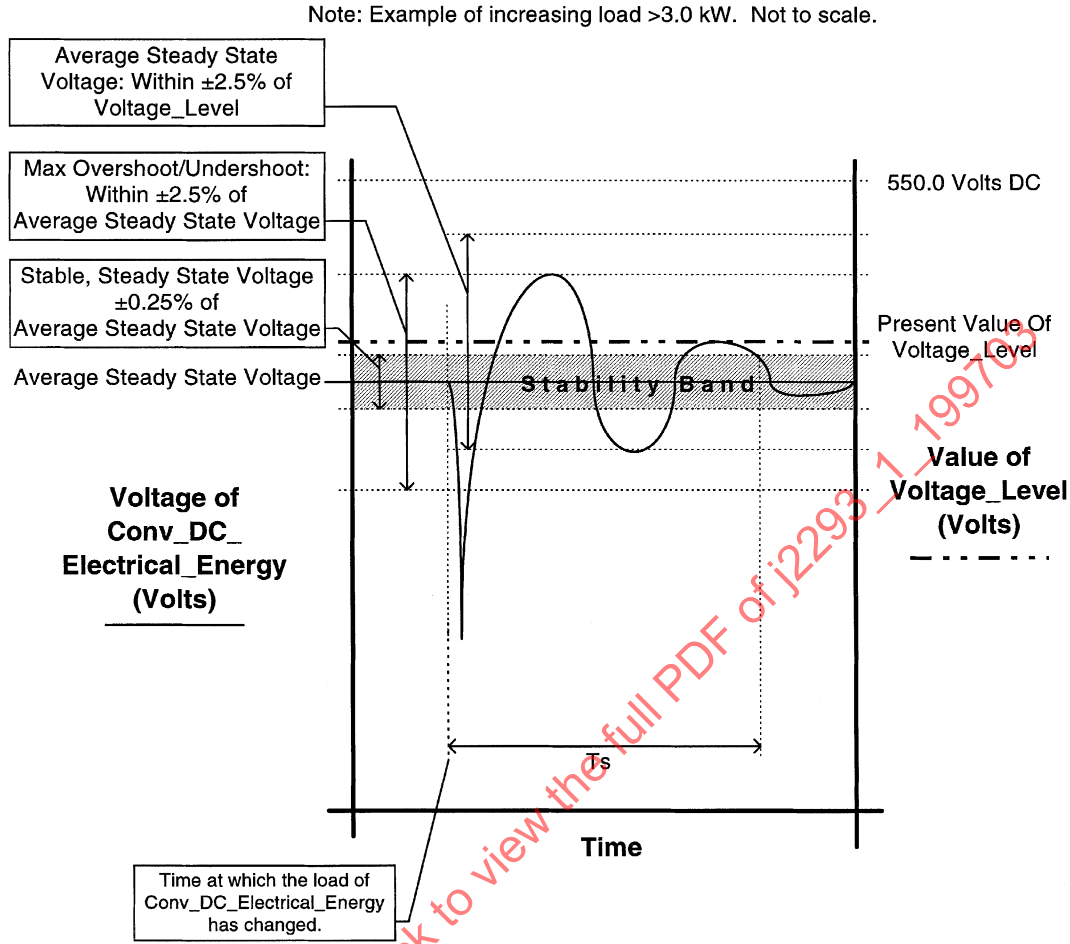

FIGURE 12—AC-TO-DC VOLTAGE CONVERSION RESPONSE

a. Minimum Conversion Power—The power of Conv_DC_Electrical_Energy shall be able to be as low as 180% W ± 10% W. See 6.3.1.7.2.3.
b. Average Steady-State Voltage—The average steady-state voltage of Conv_DC_Electrical_Energy into a constant load shall be such that:

   1. The average voltage shall be within ±2.5% of the present value of Voltage_Level
   2. The average voltage shall vary by less than 0.20 V/s
   3. The average voltage shall not exceed 512.5 V

   The average voltage at any time shall be the average of the instantaneous voltage for the succeeding 5.0 s.
c. Steady-State Voltage Stability—The voltage of Conv_DC_Electrical_Energy into a constant load shall be within ±0.25% of the average steady-state voltage while stable. This defines a stable voltage condition.
d. Maximum Load Step—The instantaneous voltage of Conv_DC_Electrical_Energy shall respond as follows to a step change of 3.0 kW or less in the load of Conv_DC_Electrical_Energy:

   1. The instantaneous voltage shall be stable in 5.0 ms or less (Ts).
   2. The instantaneous voltage shall overshoot/undershoot the average steady-state voltage by ±2.5% or less.

e. Maximum Transient Voltage—The voltage of Conv_DC_Electrical_Energy shall not exceed 550.0 V in response to any change in load of Conv_DC_Electrical_Energy.
f. Maximum Load Rate Of Change—The voltage of Conv_DC_Electrical_Energy shall remain within ±2.5% of the average steady-state voltage in response to a rate of change of 100 W/ms or less in the load of Conv_DC_Electrical_Energy:
g. Minimum Voltage Step—The average voltage level of Conv_DC_Electrical_Energy shall remain constant or increase (decrease) by an amount of from 1.0 to 2.0 V, for an increase (decrease) in Voltage_Level of 2.0 V.

6.1.3.5.3.3 Power Out Of Range—Power_Out_Of_Range shall be assigned a value of “HI” (“LO”) if the value of Power_Level required by the closed-loop voltage control is greater (less) than the active power stage can supply, as defined by Max_Stage_Power and Min_Stage_Power. Otherwise, Power_Out_Of_Range shall not be assigned a value by this process.

Stage_Power_Limited may be considered in the determination of Power_Out_Of_Range by this process.

6.1.3.6 Convert AC to DC Power—The purpose of this process is to provide open-loop conversion of AC electrical energy into DC electrical energy. The residual AC content of the DC electrical energy is constrained in order that a current measurement system that measures average current may be designed. This characteristic is also needed to be able to limit the amount of excess heating of the EV Storage Battery due to the AC content.

The exact AC content of Mod_AC_Electrical_Energy and the nominal voltage of Conv_DC_Electrical_Energy is of particular interest for a Type B architecture due to the inductive coupling. See SAE J1773 for details.

6.1.3.6.1 Input/Output Flows—See Table 13.

TABLE 13—CONVERT AC-TO-DC POWER INPUT/OUTPUT FLOWS

Flow Name	Type
Mod_AC_Electrical_Energy	Input
Conv_DC_Electrical_Energy	Output

6.1.3.6.2 Initialization—The following shall be performed once upon activation of this process: None.

6.1.3.6.3 Operation—The following shall be performed continually while this process is active:

6.1.3.6.3.1 Output Power Level—The power level of Conv_DC_Electrical_Energy shall be within ±1.0% of the power level of Mod_AC_Electrical_Energy minus a constant offset.

The power level of Conv_DC_Electrical_Energy shall stay the same or increase (decrease) as the power level of Mod_AC_Electrical_Energy stays the same or increases (decreases).

6.1.3.6.3.2 AC Content—The AC content of Conv_DC_Electrical_Energy shall be such that the ratio of the root-mean-squared (rms) power to the average power shall not exceed the value in Table 14, as a function of the average power of Mod_AC_Electrical_Energy. This shall only apply for the P1 power phase when pulse mode of operation is enabled. See 6.1.3.4.

The total power content of Conv_DC_Electrical_Energy for all frequencies from 1.0 to 40 Hz shall be less than 0.5% of its total power.

TABLE 14—MAXIMUM RATIO OF RMS TO AVERAGE POWER

Average Power Level of Mod_AC_Electrical_Energy (P)	Maximum Ratio of RMS to Average Power of Conv_DC_Electrical_Energy
$P \leq 1.5$ kW	1.60
1.5 kW $< P \leq$ 10.0 kW	1.25
$P >$ 10.0 kW	1 + (2.50 kW ⁄ P kW)

6.1.4 SWITCH DC ON/OFF—The purpose of this process is to provide on/off switching of DC_Electrical_Energy. This is needed to present de-energized circuits across the coupling for a Type C system. There may be additional switching of high voltage DC circuits between the EV Storage Battery and other on-board vehicle systems. However, this additional switching does not play a direct role in ETS.

The quality of the switch mechanism must be appropriate so that the equipment to which this process is allocated will operate properly. The exact characteristics that should be considered will vary as a function of a specific EV design and ETS architecture. Therefore, it is only practical to define general characteristics that can apply to any design or architecture.

6.1.4.1 *Input/Output Flows*—See Table 15.

TABLE 15—SWITCH DC ON/OFF INPUT/OUTPUT FLOWS

Flow Name	Type
Conv_DC_Electrical_Energy	Input
DC_Sw_Request	Input
DC_Electrical_Energy	Input/Output
Sw_DC_Electrical_Energy	Output

6.1.4.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.1.4.3 *Operation*—The following shall be performed continually while this process is active:

Conv_DC_Electrical_Energy and Sw_DC_Electrical_Energy shall be considered to be the same internal to this process.

If the value of DC_Sw_Request is “CLOSED”, then an electrical circuit between DC_Electrical_Energy and Conv_DC_Electrical_Energy shall be closed and stable within 750 ms.

If the value of DC_Sw_Request is not “CLOSED”, then an electrical circuit between DC_Electrical_Energy and Conv_DC_Electrical_Energy shall be opened and stable within 250 ms.

6.1.5 DETECT DC PRESENT—The purpose of this process is to determine if the characteristics of DC_Electrical_Energy are appropriate for proper charging of the EV storage battery.

The exact characteristics that should be considered when determining if DC_Electrical_Energy is acceptable for the charging of the EV storage battery will vary as a function of a specific EV Storage battery's design and construction. It is, therefore, only practical to define general characteristics of DC_Electrical_Energy that can apply to any design or construction.

6.1.5.1 *Input/Output Flows*—See Table 16.

TABLE 16—DETECT DC PRESENT INPUT/OUTPUT FLOWS

Flow Name	Type
DC_Electrical_Energy	Input
DC_Present	Output

6.1.5.2 Initialization—The following shall be performed once upon activation of this process: None

6.1.5.3 Operation—The following shall be performed continually while this process is active:

DC_Present shall be assigned a value of "TRUE" if the characteristics of DC_Electrical_Energy are such that it is acceptable to charge the EV Storage Battery, otherwise, it shall be assigned a value of "FALSE".

6.1.6 DETECT SWITCHED AC PRESENT—The purpose of this process is to determine if the characteristics of Sw_AC_Electrical_Energy are such that the ETS will operate properly.

The exact characteristics that should be considered when determining if Sw_AC_Electrical_Energy is appropriate for proper system operation will vary as a function of a specific system's design and architecture. It is, therefore, only practical to define general characteristics of Sw_AC_Electrical_Energy that can apply to any design or architecture.

6.1.6.1 Input/Output Flows—See Table 17.

TABLE 17—DETECT SWITCHED AC PRESENT INPUT/OUTPUT FLOWS

Flow Name	Type
Sw_AC_Electrical_Energy	Input
Sw_AC_Present	Output

6.1.6.2 Initialization—The following shall be performed once upon activation of this process: None

6.1.6.3 Operation—The following shall be performed continually while this process is active:

Sw_AC_Present shall be assigned a value of "TRUE" if the characteristics of Sw_AC_Electrical_Energy are such that the equipment to which this process is allocated shall operate properly, otherwise, it shall be assigned a value of "FALSE".

6.1.7 DETECT SWITCHED DC PRESENT—The purpose of this process is to determine if the characteristics of Sw_DC_Electrical_Energy are such that the ETS will operate properly. For a Type C (DC conductive) system this may include the verification that the EVSE has pre-charged its high-voltage capacitive elements that will be powered by Sw_DC_Electrical_Energy.

The exact characteristics that should be considered when determining if Sw_DC_Electrical_Energy is appropriate for proper system operation will vary as a function of a specific system's design and architecture. It is, therefore, only practical to define general characteristics of Sw_DC_Electrical_Energy that can apply to any design or architecture.

6.1.7.1 *Input/Output Flows*—See Table 18.

TABLE 18—DETECT SWITCHED DC PRESENT INPUT/OUTPUT FLOWS

Flow Name	Type
Sw_DC_Electrical_Energy	Input
Sw_DC_Present	Output

6.1.7.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.1.7.3 *Operation*—The following shall be performed continually while this process is active:

Sw_DC_Present shall be assigned a value of "TRUE" if the characteristics of Sw_DC_Electrical_Energy are such that the equipment to which this process is allocated shall operate properly, otherwise, it shall be assigned a value of "FALSE".

6.2 Determine Ready To Transfer Electrical Energy—The purpose of this process is to determine if the ETS is ready to transfer electrical energy. It is decomposed as shown in Figure 13, and contains logic functions that are detailed in the following tables:

Table 19—2-s1: Transfer Ready DT
Table 20—2-s2: AC Switch Request DT
Table 21—2-s3: Vent Request DT
Table 22—2-s4: DC Switch Request DT

All portions of this process are active (producing output flows) whenever the total process is active. There is no explicit process activation control. However, for a process to provide an output flow, all inputs necessary to determine that flow must be available (data triggering).

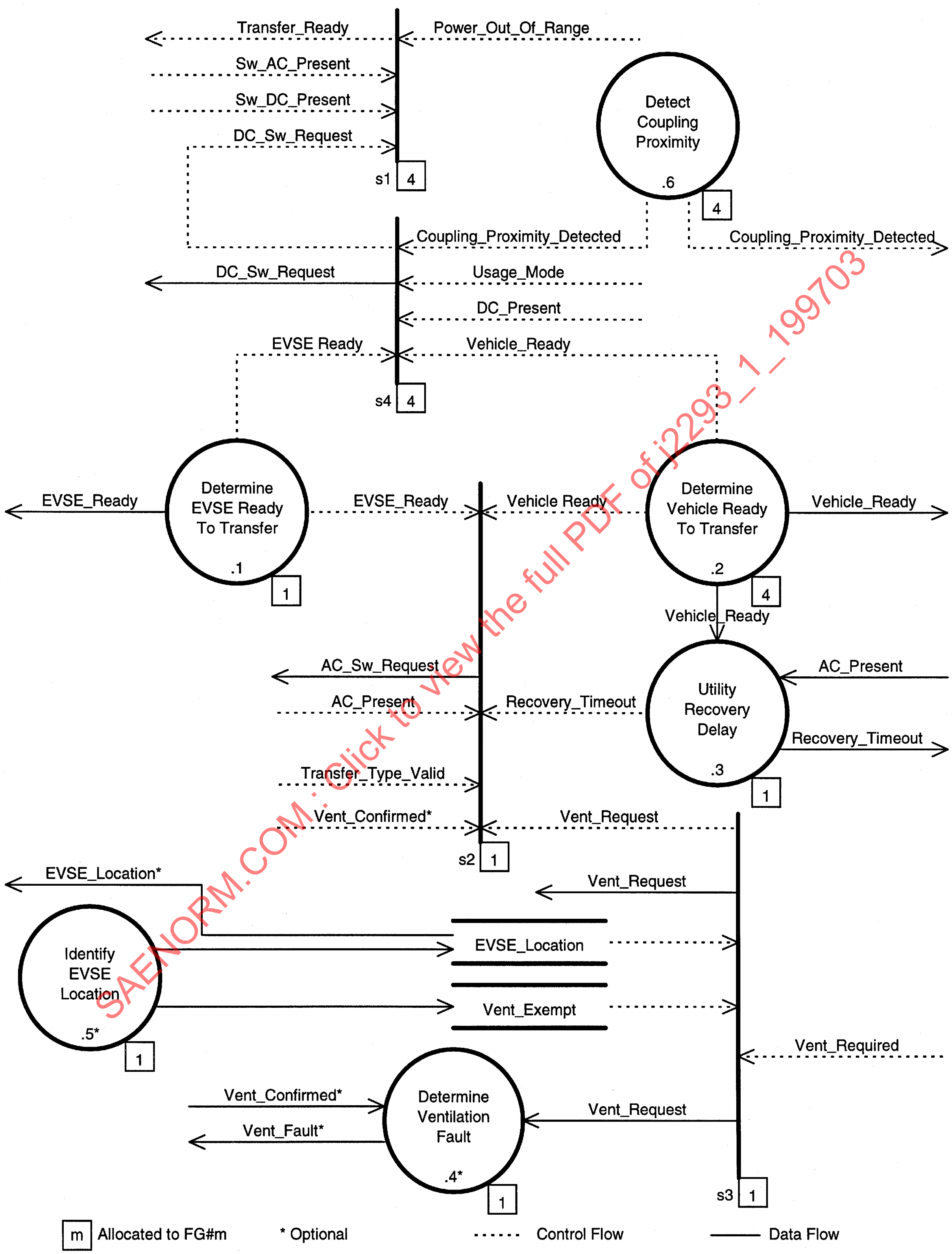

FIGURE 13—2.0: DETERMINE READY TO TRANSFER ELECTRICAL ENERGY DFD

TABLE 19—2-s1: TRANSFER READY DT

Sw_AC_Present	DC_Sw_Request = "CLOSED"	Sw_DC_Present	Power_Out_Of_Range = "OK"	Transfer_Ready
"FALSE"	Do Not Care	Do Not Care	Do Not Care	"FALSE"
Do Not Care	"FALSE"	Do Not Care	Do Not Care	"FALSE"
Do Not Care	Do Not Care	"FALSE"	Do Not Care	"FALSE"
Do Not Care	Do Not Care	Do Not Care	"FALSE"	"FALSE"
"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"

TABLE 20—2-s2: AC SWITCH REQUEST DT

Vent_ Request	Vent_ Confirmed	AC_ Present	Recovery_ Timeout	EVSE_ Ready= "READY"	Vehicle_ Ready= "READY"	Transfer_ Type_Valid	AC_Sw_ Request
"FALSE"	Do Not Care	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"CLOSE"
"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"CLOSE"
"TRUE"	"FALSE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"OPEN"
Do Not Care	Do Not Care	"FALSE"	Do Not Care	Do Not Care	Do Not Care	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	"FALSE"	Do Not Care	Do Not Care	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	Do Not Care	"FALSE"	Do Not Care	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	Do Not Care	Do Not Care	"FALSE"	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	Do Not Care	Do Not Care	Do Not Care	"FALSE"	"OPEN"

TABLE 21—2-s3: VENT REQUEST DT

Vent_Exempt	EVSE_Location	Vent_Required	Vent_Request
"TRUE"	Do Not Care	Do Not Care	"FALSE"
"FALSE"	"OUTDOOR"	Do Not Care	"FALSE"
"FALSE"	"INDOOR"	"FALSE"	"FALSE"
"FALSE"	"INDOOR"	"TRUE"	"TRUE"

TABLE 22—2-s4: DC SWITCH REQUEST DT

DC_Present	Coupling_ Proximity_ Detected	EVSE_Ready = "READY"	Vehicle_Ready = "READY"	Usage_Mode NOT= "NO_TRANSER"	DC_Sw_Request
"FALSE"	Do Not Care	Do Not Care	Do Not Care	Do Not Care	"OPEN"
Do Not Care	"FALSE"	Do Not Care	Do Not Care	Do Not Care	"OPEN"
Do Not Care	Do Not Care	"FALSE"	Do Not Care	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	"FALSE"	Do Not Care	"OPEN"
Do Not Care	Do Not Care	Do Not Care	Do Not Care	"FALSE"	"OPEN"
"TRUE"	"TRUE"	"TRUE"	"TRUE"	"TRUE"	"CLOSE"

6.2.1 DETERMINE EVSE READY TO TRANSFER—The purpose of this process is to determine if all off-vehicle equipment within the context of the ETS is in a state where it is ready to support power transfer from the Utility to the EV. This off-vehicle equipment is generally referred to as electric vehicle supply equipment (EVSE). Only conditions that directly relate to the readiness of EVSE should be considered here. Issues related to site ventilation should not be considered here, as these are considered as a part of the control structure.

The exact characteristics considered when determining that the EVSE is ready to support power transfer will vary based on manufacturers' specific EVSE designs. Further, the EVSE's functional content will vary depending on the ETS architecture (see Section 7). Therefore, it is only practical to define general requirements that could apply to any design or architecture. This results in no explicit flows into this process. Items for consideration should include, but not be limited to:

a. Access doors/panels closed
b. Internal power supply outputs within operational specification
c. Internal component temperatures within operational specification

6.2.1.1 Input/Output Flows—See Table 23.

TABLE 23—DETERMINE EVSE READY TO TRANSFER—INPUT/OUTPUT FLOWS

Flow Name	Type
EVSE_Ready	Output

6.2.1.2 Initialization—The following shall be performed once upon activation of this process:

EVSE_Ready shall be assigned the value of "NOT_READY".

6.2.1.3 Operation—The following shall be performed continually while this process is active:

EVSE_Ready shall be assigned the value of "READY" if the present state of the EVSE is such that it can support energy transfer properly, otherwise, a value of "NOT_READY" shall be assigned.

Determination of EVSE_Ready shall not take into account data or conditions that are used in the determination of Transfer_Ready, AC_Sw_Request, DC_Sw_Request, and Vent_Request, as shown in Figure 13.

6.2.2 DETERMINE VEHICLE READY TO TRANSFER—The purpose of this process is to determine if all on-board vehicle equipment within the context of the ETS is in a state where it is ready to support power transfer from the Utility to the EV. Only conditions that directly relate to the readiness of vehicles should be considered here. Issues related to site ventilation should not be considered here, as these are considered as a part of the control structure.

The exact characteristics considered when determining that the vehicle is ready to support power transfer will vary based on manufacturers' specific EV designs. Further, the vehicle's functional content will vary depending on the ETS architecture (see Section 7). Therefore, it is only practical to define general requirements that could apply to any design or architecture. This results in no explicit flows into this process. Items for consideration should include, but not be limited to:

a. Vehicle in PARK, or parking brake set
b. Access doors/panels closed
c. Internal power supply outputs within specification
d. Internal component temperatures within specification
e. High voltage equipment properly isolated/grounded

6.2.2.1 *Input/Output Flows*—See Table 24.

TABLE 24—DETERMINE VEHICLE READY TO TRANSFER—INPUT/OUTPUT FLOWS

Flow Name	Type
Vehicle_Ready	Output

6.2.2.2 *Initialization*—The following shall be performed once upon activation of this process:

Vehicle_Ready shall be assigned a value of “NOT_READY”.

6.2.2.3 *Operation*—The following shall be performed continually while this process is active:

Vehicle_Ready shall be assigned a value of “READY” if the present state of the EV is such that it can support energy transfer properly, otherwise, a value of “NOT_READY” shall be assigned.

Determination of Vehicle_Ready shall not take into account data or conditions that are used in the determination of Transfer_Ready, AC_Sw_Request, DC_Sw_Request, and Vent_Request, as shown in Figure 13.

6.2.3 UTILITY RECOVERY DELAY—The purpose of this process is to provide a random time delay to the start of the energy transfer process after a Utility recovers from a power outage. This delay is only required when the Utility recovers while an EV is connected to the EVSE. The delay will allow an opportunity for the Utility's automatic fault recovery equipment to operate without the load of EVs on the Utility. Further, the random element has the effect of slowly increasing the total EV load for the recovering portion of the Utility.

This delay may be considered inconvenient by the EV User. Therefore, this process allows the User to override the delay by briefly disconnecting the EVSE from the EV. Allowing an individual User to override the delay does not significantly reduce the effectiveness of the random delay because of the low probability that a large percentage of Users will override at the same time.

6.2.3.1 *Input/Output Flows*—See Table 25.

TABLE 25—UTILITY RECOVERY DELAY—INPUT/OUTPUT FLOWS

Flow Name	Type
AC_Present	Input
Vehicle_Ready	Input
Recovery_Timeout	Output

6.2.3.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.2.3.3 *Operation*—The following shall be performed continually while this process is active:

Recovery_Timeout shall be assigned a value of "TRUE" if either of the following 2 items are true, otherwise, it shall be assigned a value of "FALSE":

a. AC_Present is "TRUE" continually for a random period of time or longer. The random period of time shall be between 120 to 720 s with a resolution and accuracy of 1.0 s or less. A new random period shall be selected and the timing restarted each time AC_Present becomes "TRUE".
b. Vehicle_Ready is "UNDEFINED" continually for 5.0 s or longer during the timing of the 120 to 720 s random period. The timing of the 5.0 s continual period shall be restarted each time AC_Present becomes "TRUE".

6.2.4 DETERMINE VENTILATION FAULT (OPTIONAL)—The purpose of this process is to determine if the Indoor Charge Site Ventilation System is non-functional or not available. This is accomplished by allowing a fixed period of time for a functioning VS to confirm normal operation.

6.2.4.1 *Input/Output Flows*—See Table 26.

TABLE 26—DETERMINE VENTILATION FAULT—INPUT/OUTPUT FLOWS

Flow Name	Type
Vent_Confirmed	Input
Vent_Request	Input
Vent_Fault	Output

6.2.4.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.2.4.3 *Operation*—The following shall be performed continually while this process is active:

Vent_Fault shall be assigned a value of "TRUE" if both of the following 2 items are true, otherwise, it shall be assigned a value of "FALSE":

a. Vent_Request has a value of "TRUE" continually for 10.0 s or longer.
b. Vent_Confirmed has a value of "FALSE".

The resolution and accuracy of all timing parameters shall be 1.0 s or less.

6.2.5 IDENTIFY EVSE LOCATION (OPTIONAL)—The purpose of this optional process is to identify the location, indoor or outdoor, where the EVSE is installed, and to identify if the EVSE is exempt from the charge site mechanical ventilation requirements identified in the National Electric Code, Article 625.

EVSE may be designed for indoor or for outdoor service, or the equipment may be suitable for either. In that case, EVSE will accommodate some method for the location to be identified (switches, jumpers, etc.) when the equipment is installed. Further, some EVSE may be exempt from the need for charge site ventilation, regardless of the design of an EV that may be charged by it.

The exact characteristics that should be considered to determine the EVSE location and ventilation status will vary based on manufacturers' specific equipment designs. Therefore, no specific flows are shown into this process.

6.2.5.1 *Input/Output Flows*—See Table 27.

TABLE 27—IDENTIFY EVSE LOCATION—INPUT/OUTPUT FLOWS

Flow Name	Type
EVSE_Location	Output
Vent_Exempt	Output

6.2.5.2 *Initialization*—The following shall be performed once upon activation of this process:

Vent_Exempt shall be assigned the value of “TRUE” if the EVSE is considered to be exempt from the need for specific charge site mechanical ventilation, per the National Electric Code (NEC®, NFPA-70-1996), Article 625. Otherwise, Vent_Exempt shall be assigned the value of “FALSE”.

EVSE_Location shall be assigned the value of “INDOOR” if the EVSE is considered to be located indoors and that specific charge site mechanical ventilation may be required, per the National Electric Code (NEC®, NFPA-70-1996), Article 625. Otherwise, EVSE_Location shall be assigned the value of “OUTDOOR”. In the case where Vent_Exempt is “TRUE,” the value that is assigned to EVSE_Locations, if any, is of no consequence.

6.2.5.3 *Operation*—The following shall be performed continually while this process is active: None.

6.2.6 Detect Coupling Proximity—The purpose of this process is to determine if the characteristics of the connection between the EVSE and EV are such that the EV should be immobilized to prevent possible damage to the power coupling.

The exact characteristics that should be considered when determining if a full or partial connection exists will vary as a function of the specific EV design and ETS architecture. Therefore, it is only practical to define general characteristics of the coupling that could apply to any design or architecture.

6.2.6.1 *Input/Output Flows*—See Table 28.

TABLE 28—DETECT COUPLING PROXIMITY—INPUT/OUTPUT FLOWS

Flow Name	Type
Coupling_Proximity_Detected	Output

6.2.6.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.2.6.3 *Operation*—The following shall be performed continually while this process is active:

Coupling_Proximity_Detected shall be assigned a value of “TRUE” if the presence or probability of a connection between the EVSE and EV is such that the vehicle should be immobilized to prevent possible damage to the power coupling. Otherwise, Coupling_Proximity_Detected shall be assigned a value of “FALSE”.

6.3 Control Transfer of Electrical Energy—The purpose of this process is to control the transfer of electrical energy through the ETS, from the Electric Utility Power System to the EV Storage Battery. It is decomposed as shown in Figure 14.

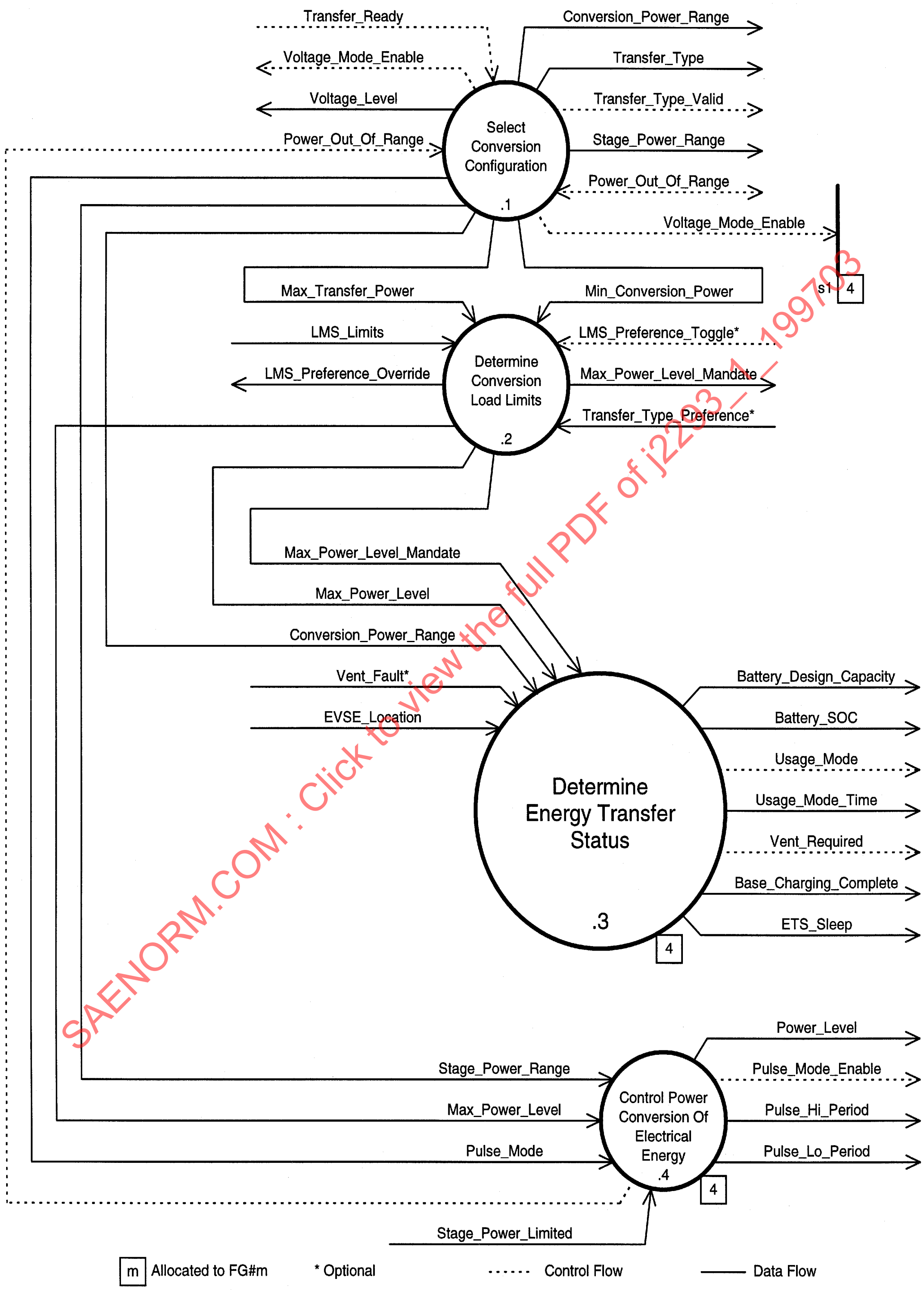

FIGURE 14—3.0: CONTROL TRANSFER OF ELECTRICAL ENERGY DFD

Explicit activation of portions of this process shall be as described by Table 29. However, for any process to produce an output flow, all inputs necessary to determine that output must be available (data triggered).

TABLE 29—3.0-s1: VOLTAGE MODE PAT

Voltage_Mode_Enable	3.4 Control Power Conversion of Electrical Energy	3.5 Control Voltage Conversion of Electrical Energy
“FALSE”	Activate	Disable
“TRUE”	Disable	Activate

6.3.1 SELECT CONVERSION CONFIGURATION—The purpose of this process is to identify the power conversion configuration and capabilities of the ETS, and then to select from the available options. It is decomposed as shown in Figure 15. It is expected that most equipment which offers a broad range of power conversion level will do so in distinct stages with overlapping power ranges as shown in Figure 16. However, it is acceptable to have a single stage.

Explicit activation of portions of this process shall be controlled as described in:

a. Table 30—3.1-s1: Conversion Identification PAT
b. Table 31—3.1-s2: Conversion Selection PAT

However, for a process to produce an output flow, all input flows necessary to determine that flow must be available (data triggered).

TABLE 30—3.1-s1: CONVERSION IDENTIFICATION PAT

Transfer_Ready	Max_Transfer_Power_Valid	3.1.2 Identify Stage Design Range	3.1.7 Identify Conversion Power Range
“FALSE”	“FALSE”	Disable	Disable
“FALSE”	“TRUE”	Activate	Activate
“TRUE”	Do Not Care	Disable	Activate

TABLE 31—3.1-s2: CONVERSION SELECTION PAT

Transfer_Ready	3.1.1 Select Power Stage	3.1.3 Select Conversion Control	3.1.5 Select Transfer Type
“FALSE”	Activate	Activate	Activate
“TRUE”	Disable	Disable	Disable

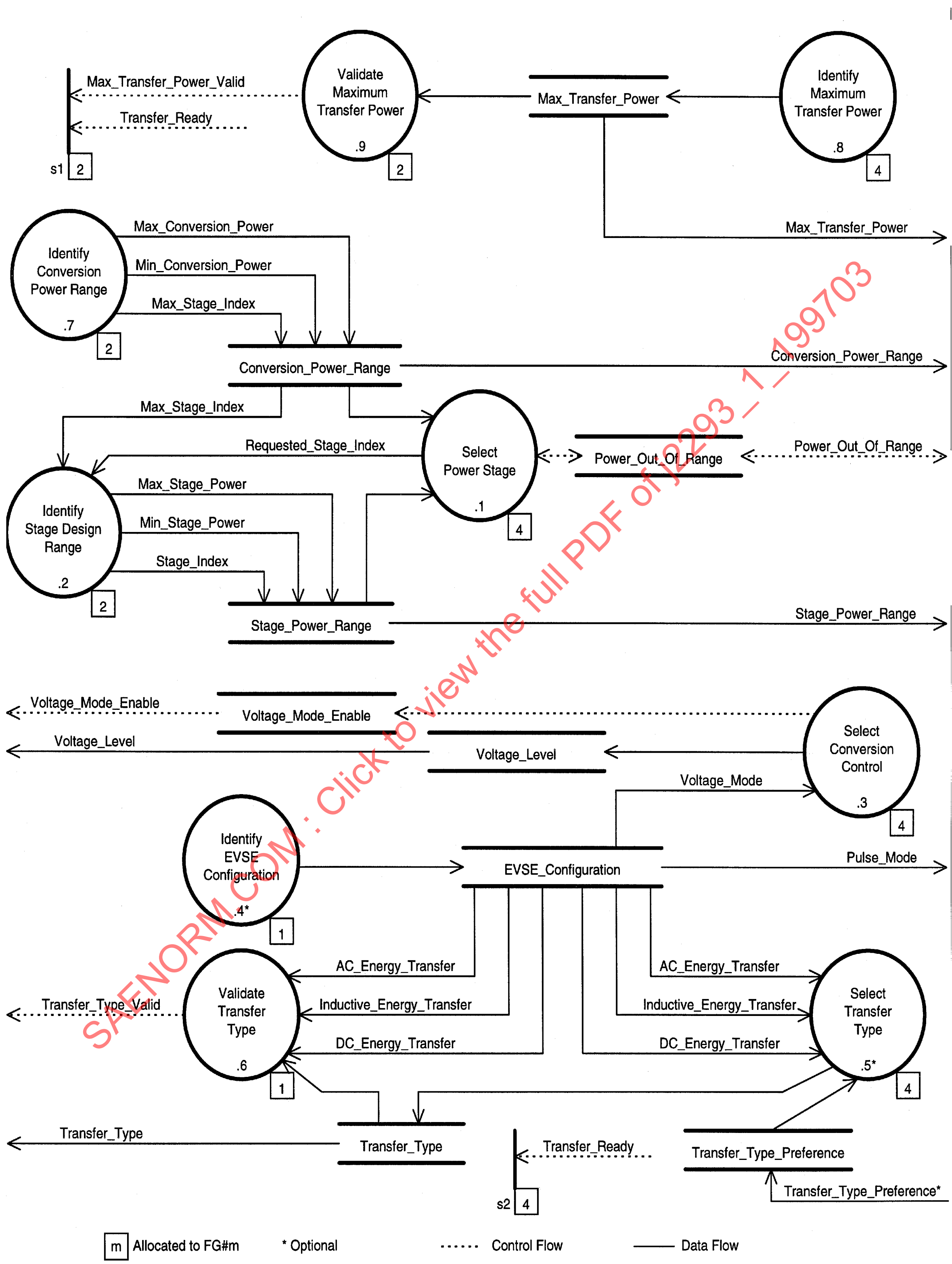

FIGURE 15—3.1: SELECT CONVERSION CONFIGURATION DFD

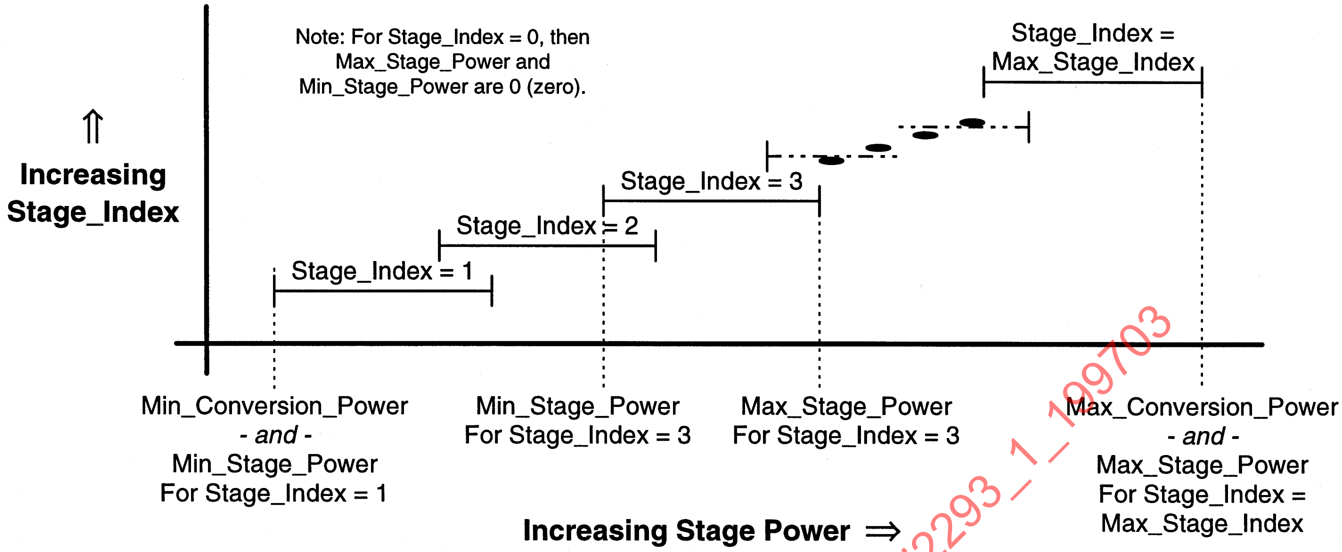

FIGURE 16—RELATIVE CONVERSION STAGE POWER RANGE

6.3.1.1 *Select Power Stage*—The purpose of this process is to select which power stage of the AC-to-AC conversion equipment is to be active. The power conversion capabilities of the present stage are examined and a decision is made if that stage is acceptable for energy transfer. If not, a different stage is selected. It may be necessary to examine all the capabilities of all stages before a decision can be made.

The exact characteristics that should be considered to select the active power stage will vary based on manufacturers' specific vehicle designs and the present energy transfer strategy.

6.3.1.1.1 Input/Output Flows—See Table 32.

TABLE 32—SELECT POWER STAGE INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Conversion_Power	Input
Max_Stage_Index	Input
Max_Stage_Power	Input
Min_Conversion_Power	Input
Min_Stage_Power	Input
Stage_Index	Input
Power_Out_Of_Range	Input/Output
Requested_Stage_Index	Output

6.3.1.1.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.1.1.3 Operation—The following shall be performed continually while this process is active:

6.3.1.1.3.1 Requested Stage Index—Requested_Stage_Index shall be assigned a value that represents which power stage of the AC-to-AC conversion equipment is to be active such that:

a. The value shall range between 0 (zero) and Max_Stage_Index, inclusive.
b. The value shall be selected such that the values of Min_Stage_Power, Max_Stage_Power are acceptable for the present energy transfer strategy.
c. The value shall be 0 (zero) to select a null stage, if no stage is acceptable for the present energy transfer strategy.

The value of Power_Out_Of_Range and Stage_Index should be considered when determining Requested_Stage_Index. If the value of Power_Out_Of_Range is “LO” (“HI”), this indicates that a value that is less (greater) than Stage_Index should be assigned to Requested_Stage_Index.

6.3.1.1.3.2 Power Out Of Range—Power_Out_Of_Range shall be assigned the value of “OK” if the values of Min_Stage_Power, Max_Stage_Power, and Stage_Index are acceptable for the present energy transfer strategy and the value of Stage_Index is not 0 (zero). Otherwise, no value shall be assigned.

6.3.1.2 Identify Stage Design Range—The purpose of this process is to identify the unlimited steady-state power conversion capabilities of the selected AC-to-AC conversion power stage. The capabilities have been constrained so that adjacent power stages must have a minimum amount of overlap.

The actual maximum power that a stage can provide may be limited to a value less than the identified maximum capability. See 6.1.3.2.3.3.

The exact characteristics that should be considered to identify the power conversion capabilities will vary based on manufacturers’ specific converter designs. Therefore, no converter-specific flows are shown into this process.

6.3.1.2.1 Input/Output Flows—See Table 33.

TABLE 33—IDENTIFY STAGE DESIGN RANGE—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Stage_Index	Input
Requested_Stage_Index	Input
Stage_Index	Output
Max_Stage_Power	Output
Min_Stage_Power	Output

6.3.1.2.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.1.2.3 Operation—The following shall be performed continually while this process is active:

6.3.1.2.3.1 Minimum Stage Power—Min_Stage_Power shall be assigned a value that represents the minimum steady-state power of Conv_AC_Electrical_Energy for the power stage indicated by Requested_Stage_Index, given the design of the stage such that:

a. The steady-state power of Conv_AC_Electrical_Energy shall be less than Min_Stage_Power +10%, and shall be greater than Min_Stage_Power –10% for the case where the value of Power_Level is equal to Min_Stage_Power, as shown in Figure 9.
b. The value shall be Min_Conversion_Power for the case where the value of Requested_Stage_Index is 1 (one).

c. The value shall be 0 W for the case where the value of Requested_Stage_Index is less than or equal to 0 (zero), or greater than Max_Stage_Index.
d. The value shall be as indicated in Table 34, based on the value of Max_Stage_Power for the adjacent lower power stage, if any.

TABLE 34—MINIMUM STAGE POWER VALUES

Max_Stage_Power for Power Stage n	Min_Stage_Power for Power Stage n+1
>6.0 kW	≤(Max_Stage_Power, for Stage n) – 2.0 kW
>2.0 kW, ≤6.0 kW	<+(Max_Stage_Power, for Stage n) –0.5 kW
≤2.0 kW	≥(Max_Stage_Power, for Stage n)

6.3.1.2.3.2 Maximum Stage Power—Max_Stage_Power shall be assigned a value that represents the maximum, unlimited steady-state power of Conv_AC_Electrical_Power for the power stage indicated by Requested_Stage_Index, given the design of the stage such that:

a. The steady-state power of Conv_AC_Electrical_Power shall be less than Max_Stage_Power +10% for the case where Power_Level is greater than or equal to Max_Stage_Power, as shown in Figure 9.
b. The value shall be Max_Conversion_Power for the case where the value of Requested_Stage_Index is equal to Max_Stage_Index.
c. The value shall be 0 W for the case where the value of Requested_Stage_Index is less than or equal to 0 (zero), or greater than Max_Stage_Index.
d. The value shall be as indicated in Table 35, based on the value of Min_Stage_Power.

TABLE 35—MAXIMUM STAGE POWER VALUES

Min_Stage_Power	Max_Stage_Power
>10.0 kW	≥Min_Stage_Power + 12.0 kW
>1.5 kW, ≤10.0 kW	≥Min_Stage_Power + 4.0 kW
≤1.5 kW	≥Min_Stage_Power

6.3.1.2.3.3 Stage Index—Stage_Index shall be assigned the value of Requested_Stage_Index, if the value of Requested_Stage_Index is an integer between 1 and Max_Stage_Index, inclusive. Otherwise, a value of 0 (zero) shall be assigned.

6.3.1.3 Select Conversion Control—The purpose of this process is to select the method of conversion control. There are two methods available: power control and voltage control.

The exact characteristics that should be considered to determine the desired conversion control will vary based on manufacturers' specific transfer strategy. Therefore, no strategy specific flows are shown into this process.

6.3.1.3.1 Input/Output Flows—See Table 36.

TABLE 36—SELECT CONVERSION CONTROL—INPUT/OUTPUT FLOWS

Flow Name	Type
Voltage_Mode	Input
Voltage_Level	Output
Voltage_Mode_Enable	Output

6.3.1.3.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.1.3.3 Operation—The following shall be performed continually while this process is active:

6.3.1.3.3.1 Voltage Mode Enable—Voltage_Mode_Enable shall be assigned a value of "TRUE" if the present energy transfer strategy calls for off-board closed-loop voltage control of Conv_DC_Electrical_Energy as described in 6.1.3.5 and Voltage_Mode has the value "SUPPORTED". Otherwise, Voltage_Mode_Enable shall be assigned a value of "FALSE".

If the value of Voltage_Mode is "NOT_SUPPORTED", then the EVSE is not designed to support a closed-loop voltage control mode of operation. See 6.3.1.4.

6.3.1.3.3.2 Voltage Level—If Voltage_Mode_Enable is assigned a value of "TRUE" above, then Voltage_Level shall be assigned a value that indicates the desired voltage of Conv_DC_Electrical_Energy, otherwise, no value shall be assigned.

6.3.1.4 Identify EVSE Configuration—The purpose of this process is to identify the configuration of the electric vehicle supply equipment (EVSE). The ETS offers various architectures and some optional features. EVSE may support multiple architectures and some features are not a part of the EVSE for a particular architecture. This process is always allocated to the off-board equipment (EVSE).

The exact characteristics that should be considered to identify the EVSE configuration will vary based on a manufacturer's specific equipment design. Therefore, no explicit flows are shown into this process.

6.3.1.4.1 Input/Output Flows—See Table 37.

TABLE 37—IDENTIFY EVSE CONFIGURATION—INPUT/OUTPUT FLOWS

Flow Name	Type
AC_Energy_Transfer	Output
Inductive_Energy_Transfer	Output
DC_Energy_Transfer	Output
Pulse_Mode	Output
Voltage_Mode	Output

6.3.1.4.2 Initialization—The following shall be performed once upon activation of this process:

6.3.1.4.2.1 AC Energy Transfer—AC_Energy_Transfer shall be assigned a value of "SUPPORTED" if the EVSE is compatible with the ETS Type A architecture, otherwise, a value of "NOT_SUPPORTED" shall be assigned.

6.3.1.4.2.2 Inductive Energy Transfer—Inductive_Energy_Transfer shall be assigned a value of "SUPPORTED" if the EVSE is compatible with the ETS Type B architecture, otherwise, a value of "NOT_SUPPORTED" shall be assigned.

6.3.1.4.2.3 DC Energy Transfer—DC_Energy_Transfer shall be assigned a value of "SUPPORTED" if the EVSE is compatible with the ETS Type C architecture, otherwise, a value of "NOT_SUPPORTED" shall be assigned.

6.3.1.4.2.4 Pulse Mode—Pulse_Mode shall be assigned a value of "SUPPORTED" if the EVSE supports the optional mode of operation described in 6.1.3.4 and the EVSE is compatible with the ETS Type B or C architecture. Otherwise, a value of "NOT_SUPPORTED" shall be assigned.

While an ETS of any architecture may support this option, the EVSE only plays a direct role in a Type B or C architecture.

This is referred to as Option 1 (O1) in Section 7.

6.3.1.4.2.5 Voltage Mode—Voltage_Mode shall be assigned a value of "SUPPORTED" if the EVSE supports the optional mode of operation described in 6.1.3.5 and the EVSE is compatible with the ETS Type C architecture. Otherwise, a value of "NOT_SUPPORTED" shall be assigned.

While an ETS of any architecture may support this option, the EVSE only plays a direct role in a Type C architecture.

This is referred to as Option 2 (O2) in Section 7.

6.3.1.4.3 Operation—The following shall be performed continually while this process is active: None

6.3.1.5 Select Transfer Type—The purpose of this process is to select the form of energy that will be transferred to the vehicle from the EVSE. It is anticipated that some vehicles may support energy transfer of more than one form. This process is always allocated to the on-board equipment (EV).

The exact characteristics that should be considered to select the form of energy will vary based on manufacturers' specific vehicle designs and the present energy transfer strategy. Therefore, no vehicle-specific flows are shown into this process.

6.3.1.5.1 Input/Output Flows—See Table 38.

TABLE 38—SELECT TRANSFER TYPE—INPUT/OUTPUT FLOWS

Flow Name	Type
AC_Energy_Transfer	Input
DC_Energy_Transfer	Input
Inductive_Energy_Transfer	Input
Transfer_Type_Preference	Input
Transfer_Type	Output

6.3.1.5.2 Initialization—The following shall be performed once upon activation of this process:

Transfer_Type shall be assigned one of the values in Table 39, as a function of the values of AC_Energy_Transfer, Inductive_Energy_Transfer, and DC_Energy_Transfer, indicating the form of energy to be transferred to the vehicle, as defined in Table 40.

TABLE 39—TRANSFER TYPE OPTIONS

AC_Energy_Transfer	Inductive_Energy_Transfer	DC_Energy_Transfer	Transfer_Type
“NOT SUPPORTED	“NOT_SUPPORTED”	“NOT_SUPPORTED”	“NO_TRANSFER”
“SUPPORTED”	“NOT_SUPPORTED”	“NOT_SUPPORTED”	“AC” OR “NO_TRANSFER”
“NOT_SUPPORTED”	“SUPPORTED”	“NOT_SUPPORTED”	“INDUCTIVE” OR “NO_TRANSFER”
“SUPPORTED”	“SUPPORTED”	“NOT_SUPPORTED”	“AC” OR “INDUCTIVE” OR “NO_TRANSFER”
“NOT_SUPPORTED”	“NOT_SUPPORTED”	“SUPPORTED”	“DC” OR “NO_TRANSFER”
“SUPPORTED”	“NOT_SUPPORTED”	“SUPPORTED”	“AC” OR “DC” OR “NO_TRANSFER”
“NOT_SUPPORTED”	“SUPPORTED”	“SUPPORTED”	“INDUCTIVE” OR “DC” OR “NO_TRANSFER”
“SUPPORTED”	“SUPPORTED”	“SUPPORTED”	“AC” OR “INDUCTIVE” OR “DC” OR “NO_TRANSFER”

TABLE 40—TRANSFER TYPE DEFINITION

Transfer_Type	Definition
“NO_TRANSFER”	Energy is not to be transferred to the vehicle
“AC”	Energy transferred to the vehicle is to be in the form of AC electrical energy
“INDUCTIVE”	Energy transferred to the vehicle is to be in the form of inductive (magnetic) energy
“DC”	Energy transferred to the vehicle is to be in the form of DC electrical energy

If a particular form of energy is preferred by the EV User, indicated by the value of Transfer_Type_Preference, then this preference shall be considered if it is supported. It is not required that the preferred form of energy be transferred.

6.3.1.5.3 Operation—The following shall be performed continually while this process is active: None

6.3.1.6 Validate Transfer Type—The purpose of this process is to determine if the form of energy selected to be transferred to the vehicle is valid.

6.3.1.6.1 Input/Output Flows—See Table 41.

TABLE 41—VALIDATE TRANSFER TYPE—INPUT/OUTPUT FLOWS

Flow Name	Type
AC_Energy_Transfer	Input
DC_Energy_Transfer	Input
Inductive_Energy_Transfer	Input
Transfer_Type	Input
Transfer_Type_Valid	Output

6.3.1.6.2 Initialization—The following shall be performed once upon activation of this process: None

6.3.1.6.3 Operation—The following shall be performed continually while this process is active:

Transfer_Type_Valid shall be assigned a value of "TRUE" if any single one of the 3 following items is true. If none, or more than one item is true, a value of "FALSE" shall be assigned:

a. AC_Energy_Transfer has the value "SUPPORTED" and Transfer_Type has the value of "AC".
b. Inductive_Energy_Transfer has the value "SUPPORTED" and Transfer_Type has the value of "INDUCTIVE".
c. DC_Energy_Transfer has the value "SUPPORTED" and Transfer_Type has the value of "DC".

6.3.1.7 Identify Conversion Power Range—The purpose of this process is to identify the minimum and maximum power capabilities, and the number of power stages that are supported by the AC-to-AC conversion equipment. The capabilities have been constrained so that power stages must be able to fully charge the EV Storage Battery under most residential situations (> 1.5 kW, ≤ 10.0 kW).

The exact characteristics that should be considered to identify the conversion power range will vary based on a manufacturer's specific converter design. Therefore, no explicit flows are shown into this process.

6.3.1.7.1 Input/Output Flows—See Table 42.

TABLE 42—IDENTIFY CONVERSION POWER RANGE—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Stage_Index	Output
Max_Conversion_Power	Output
Min_Conversion_Power	Output

6.3.1.7.2 Initialization—The following shall be performed once upon activation of this process:

6.3.1.7.2.1 Maximum Stage Index—Max_Stage_Index shall be assigned an integer value between 1 and 63, inclusive, that indicates the total number of power stages that are provided by the AC-to-AC conversion equipment.

6.3.1.7.2.2 Maximum Conversion Power—Max_Conversion_Power shall be assigned a value that is equal to the value of Max_Stage_Power for the case where the value of Stage_Index is Max_Stage_Index. See 6.3.1.2.

6.3.1.7.2.3 Minimum Conversion Power—Min_Conversion_Power shall be assigned a value that meets the following:

a. The value shall be equal to the value of Min_Stage_Power for the case where the value of Stage_Index is 1 (one). See 6.3.1.2.
b. The value shall be as indicated in Table 9, based on the value of Max_Conversion_Power. See 6.1.3.2.
c. The value shall be less than or equal to 180 W regardless of the value of Max_Conversion_Power if the system supports Voltage_Mode. See 6.3.1.4.

6.3.1.7.3 Operation—The following shall be performed continually while this process is active: None.

6.3.1.8 *Identify Maximum Transfer Power*—The purpose of this process is to identify the maximum electrical power that can be transferred to the vehicle. It is expected that a vehicle will be designed to accommodate a maximum power transfer level, regardless of the EV Storage Battery's maximum charging level. This process is always allocated to the on-board equipment (EV).

The exact characteristics that should be considered to determine the maximum power transfer level will vary based on manufacturers' specific vehicle designs and ETS architecture. Therefore, no vehicle-specific flows are shown into this process.

6.3.1.8.1 Input/Output Flows—See Table 43.

TABLE 43—IDENTIFY MAXIMUM TRANSFER POWER—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Transfer_Power	Output

6.3.1.8.2 Initialization—The following shall be performed once upon activation of this process:

Max_Transfer_Power shall be assigned a value that indicates the maximum energy transfer rate (power) that can be accommodated by the equipment to which this process is allocated (vehicle).

6.3.1.8.3 Operation—The following shall be performed continually while this process is active: None.

6.3.1.9 *Validate Maximum Transfer Power*—The purpose of this process is to determine if the identified maximum electrical power that can be transferred to the vehicle is valid.

6.3.1.9.1 Input/Output Flows—See Table 44.

TABLE 44—VALIDATE MAXIMUM TRANSFER POWER—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Transfer_Power	Input
Max_Transfer_Power_Valid	Output

6.3.1.9.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.1.9.3 Operation—The following shall be performed continually while this process is active:

Max_Transfer_Power_Valid shall be assigned a value of "FALSE" if the value of Max_Transfer_Power is less than or equal to 0 W, otherwise, a value of "TRUE" shall be assigned.

6.3.2 DETERMINE CONVERSION LOAD LIMIT—The purpose of this process is to determine limits for the AC-to-AC conversion process that are based on information from the external Load Management System (LMS), the size of the branch circuit that the EVSE is connected to, and the vehicle's power transfer capability. It is decomposed as shown in Figure 17.

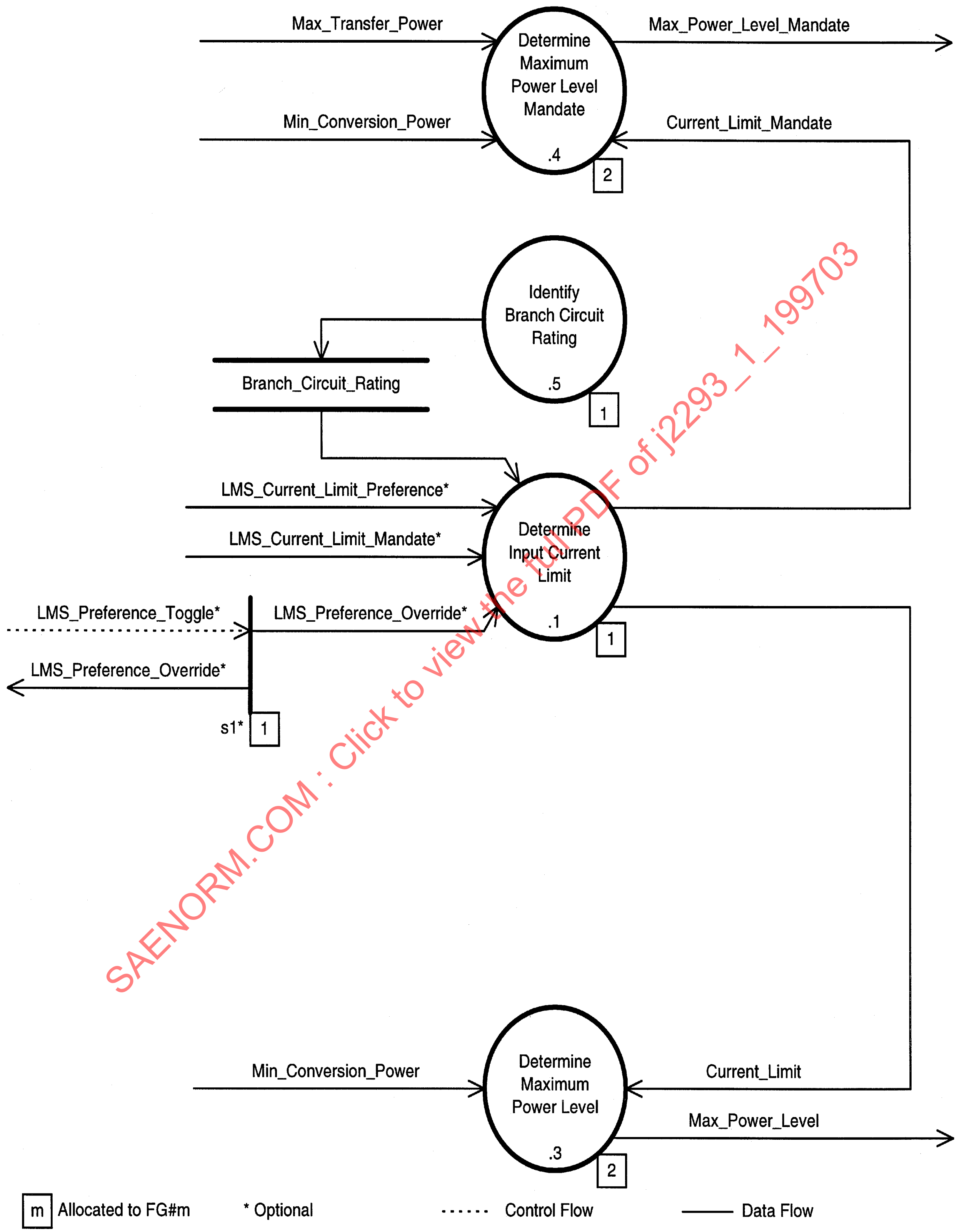

FIGURE 17—3.2: DETERMINE CONVERSION LOAD LIMITS DFD

This process will not limit energy transfer to zero even when there is a specific LMS request to do so, except if the minimum conversion capability would exceed the branch circuit rating. It would be detrimental to some vehicles if they were required to limit their load to zero for extended periods of time. See Figure 18.

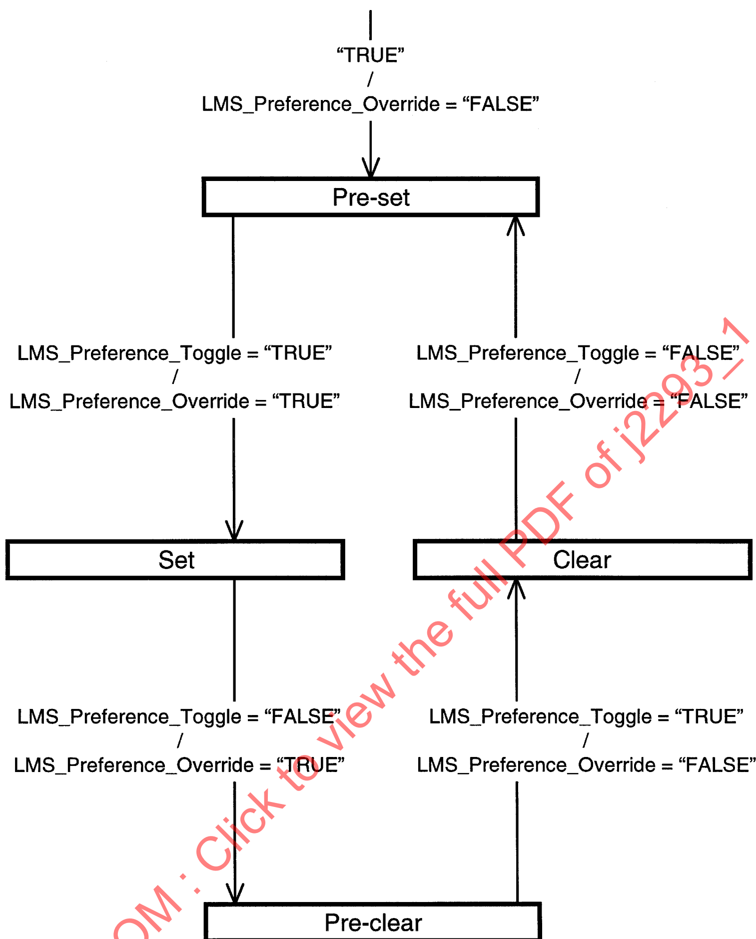

FIGURE 18—3.2-S1: LMS PREFERENCE OVERRIDE STD

6.3.2.1 *Determine Input Current Limit*—The purpose of this process is to determine the maximum input current of the AC-to-AC conversion process. This is the maximum current to be drawn from the Utility. This will be based on the rating of the branch circuit that feeds the EVSE and input from the LMS. However, the LMS can not limit the ETS to less than 1500 W of load.

The EVSE is considered to be a continuous load by the NEC®. Therefore, the branch circuit current is limited to 80% of the circuit's rating.

6.3.2.1.1 Input/Output Flows—See Table 45.

**TABLE 45—DETERMINE INPUT CURRENT LIMIT—
INPUT/OUTPUT FLOWS**

Flow Name	Type
Branch_Circuit_Rating	Input
LMS_Current_Limit_Mandate	Input
LMS_Current_Limit_Preference	Input
LMS_Preference_Override	Input
Current_Limit	Output
Current_Limit_Mandate	Output

6.3.2.1.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.2.1.3 Operation—The following shall be performed continually while this process is active:

6.3.2.1.3.1 Current Limit Mandate—Current_Limit_Mandate shall be assigned a value that is the minimum value of the following 2 items:

a. 80% of Branch_Circuit_Rating
b. The maximum value of the following 2 items:

   1. LMS_Current_Limit_Mandate
   2. The value of the current of AC_Electrical_Energy ±5% when the power of AC_Electrical_Energy is 1500 W at its nominal voltage.

6.3.2.1.3.2 Current Limit—If LMS_Preference_Override is “FALSE”, then Current_Limit shall be assigned a value that is the minimum value of the following 3 items:

a. 80% of Branch_Circuit_Rating
b. LMS_Current_Limit_Preference
c. LMS_Current_Limit_Mandate

If LMS_Preference_Override is “TRUE”, then Current_Limit shall be assigned a value that is the same as Current_Limit_Mandate.

6.3.2.2 (Section Deleted)

6.3.2.3 Determine Maximum Power Level—The purpose of this process is to determine the maximum level of AC-to-AC power conversion that will be accommodated at this time. It takes into account input current limitations and the AC-to-AC conversion minimum controlled output capability.

6.3.2.3.1 Input/Output Flows—See Table 46.

**TABLE 46—DETERMINE MAXIMUM POWER LEVEL—
INPUT/OUTPUT FLOWS**

Flow Name	Type
Current_Limit	Input
Mn_Conversion_Power	Input
Max_Power_Level	Output

6.3.2.3.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.2.3.3 Operation—The following shall be performed continually while this process is active:

6.3.2.3.3.1 Maximum Power Level—If the value of Power_Level that causes the current of Sw_AC_Electrical_Energy to be Current_Limit, +0%, –10%, is less than Min_Conversion_Power, then Max_Power_Level shall be assigned a value of 0 W, otherwise, Max_Power_Level shall be assigned the value of Power_Level that causes the current of Sw_AC_Electrical_Energy to be Current_Limit, +0%, –10%.

6.3.2.3.3.2 Maximum Power Level Rate Of Change—Max_Power_Level shall have a limited rate of change such that it shall increase at a rate less than 1500 W/s and shall decrease at a rate less than 9500 W/s.

6.3.2.4 Determine Maximum Power Level Mandate—The purpose of this process is to determine the maximum level of AC-to-AC power conversion that can be accommodated if the LMS preferences are overridden. This level should not be exceeded for any reason.

6.3.2.4.1 Input/Output Flows—See Table 47.

TABLE 47—DETERMINE MAXIMUM POWER LEVEL MANDATE—INPUT/OUTPUT FLOWS

Flow Name	Type
Max_Transfer_Power	Input
Current_Limit_Mandate	Input
Min_Conversion_Power	Input
Max_Power_Level_Mandate	Output

6.3.2.4.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.2.4.3 Operation—The following shall be performed continually while this process is active:

6.3.2.4.3.1 Maximum Power Level Mandate—If the value of Power_Level that causes the current of Sw_AC_Electrical_Energy to be Current_Limit_Mandate, +0%, –10%, is less than Min_Conversion_Power, then Max_Power_Level_Mandate shall be assigned a value of 0 W, otherwise, Max_Power_Level_Mandate shall be assigned a value that is the minimum of the following 2 items:

a. Max_Transfer_Power
b. The value of Power_Level that causes the current of Sw_AC_Electrical_Energy to be Current_Limit_Mandate, +0%, –10%.

6.3.2.4.3.2 Maximum Power Level Mandate Rate Of Change—Max_Power_Level_Mandate shall have a limited rate of change such that it shall increase at a rate less than 1500 W/s and shall decrease at a rate less than 9500 W/s.

6.3.2.5 Identify Branch Circuit Rating—The purpose of this process is to identify the current rating of the branch circuit that provides Utility power to the EVSE. It is expected that the EVSE will be designed to be connected to a branch circuit of a specific rating, or that the equipment will accommodate a method for the circuit rating to be identified (switches, jumpers, etc.) when the equipment is installed. This process is always allocated to the off-board equipment (EVSE)

The exact characteristics that should be considered to determine the branch circuit rating will vary based on manufacturers' specific equipment designs. Therefore, no specific flows are shown into this process.

6.3.2.5.1 Input/Output Flows—See Table 48.

TABLE 48—IDENTIFY BRANCH CIRCUIT RATING—INPUT/OUTPUT FLOWS

Flow Name	Type
Branch_Circuit_Rating	Output

6.3.2.5.2 Initialization—The following shall be performed once upon activation of this process:

Branch_Circuit_Rating shall be assigned a value that indicates the rated amperage of the branch circuit that provides Utility power to the EVSE.

6.3.2.5.3 Operation—The following shall be performed continually while this process is active: None.

6.3.3 DETERMINE ENERGY TRANSFER STATUS—The purpose of this process is to determine the status of the present energy transfer strategy.

Storage batteries and vehicle systems will differ from individual vehicle manufacturers, as well as between vehicles from the same manufacturer. Different batteries and different high voltage power systems will require different energy transfer strategies. Therefore, it is not practical to require or define exact charge control strategies or exact transfer strategies in this document.

All electric vehicle charging systems (specific battery charging equipment applied to a specific vehicle/battery) are identified as one of two types with respect to National Electric Code (NEC®, NFPA-70-1996), Article 625—Electric Vehicle Charging System Equipment. The types are:

a. Those that have been certified as "...suitable to be charged indoors..." and, therefore, do not require specific mechanical ventilation for an indoor charging site.
b. All others, considered suitable for indoor charging if, and only if, appropriate mechanical ventilation is operating at the indoor charging site.

An individual vehicle, typically with a fixed battery design, may be capable of multiple charge control strategies using the same charging equipment. The use of different strategies may alter the charging system's need for mechanical ventilation for indoor charging. There are no restrictions that prevent changing strategy to accommodate various indoor charging sites that may not have mechanical ventilation.

6.3.3.1 *Input/Output Flows*—See Table 49.

TABLE 49—DETERMINE ENERGY TRANSFER STATUS—INPUT/OUTPUT FLOWS

Flow Name	Type
EVSE_Location	Input
Max_Conversion_Power	Input
Max_Power_Level	Input
Max_Power_Level_Mandate	Input
Max_Stage_Index	Input
Min_Conversion_Power	Input
Vent_Fault	Input
Base_Charging_Complete	Output
Battery_Design_Capacity	Output
Battery_SOC	Output
ETS_Sleep	Output
Usage_Mode	Output
Usage_Mode_Time	Output
Vent_Required	Output

6.3.3.2 *Initialization*—The following shall be performed once upon activation of this process: None.

6.3.3.3 *Operation*—The following shall be performed continually while this process is active:

6.3.3.3.1 Usage Mode—Usage_Mode shall be assigned a value that indicates the purpose that energy transferred to the vehicle will be, or is presently being used for, given the present energy transfer strategy, as defined in Table 50.

TABLE 50—USAGE_MODE DEFINITION

Usage_Mode	Definition
"NO_TRANSER"	No energy transfer to the vehicle or battery is occurring or desired.
"BASE"	Energy is/will be used to charge the battery to base charge completion and to support other high voltage vehicle systems. When this mode is complete, the battery is to be considered fully charged by EV User.
"OVER"	Energy is/will be used to perform equalization maintenance (overcharge) of the battery and to support other high voltage vehicle systems. Interrupting this mode will not significantly affect the range of the vehicle. For this mode to be in effect, the BASE mode must have successfully completed (Base_Charging_Complete = "TRUE").
"SUPPORT"	Energy will not be used to charge the battery. It will be used to support other high voltage vehicle systems.

6.3.3.3.2 Usage Mode Time—Usage_Mode_Time shall be assigned a value that indicates an estimate of the period of time that energy transferred to the vehicle will be, or will continue to be used for, for the present Usage_Mode. Usage_Mode_Time shall indicate 0 (zero) when no estimate is available or possible.

6.3.3.3.3 Ventilation Required—Vent_Required shall be assigned the value "TRUE" if mechanical ventilation for indoor charging is required for the present energy transfer strategy and the present EV Storage Battery, per the National Electric Code (NEC®, NFPA-70-1996), Article 625. Otherwise, Vent_Required shall be assigned the value "FALSE".

The value of EVSE_Location may be considered when selecting the present energy transfer strategy.

If Vent_Required has the value "TRUE" and Vent_Fault has the value "TRUE", then energy transfer will not be allowed. In this situation, a different energy transfer strategy that will cause Vent_Required to be assigned, the value "FALSE" should be considered.

6.3.3.3.4 Base Charging Complete—Base_Charging_Complete shall be assigned the value of "TRUE" if the "BASE" Usage_Mode has been successfully completed. Otherwise, Base_Charging_Complete shall be assigned the value of "FALSE".

6.3.3.3.5 Battery State of Charge—Battery_SOC shall be assigned a value that is an estimate of the present percent fraction content of the EV Storage Battery's usable energy content when fully charged (100%).

It is not required that Battery_SOC have a value of 100% when Base_Charging_Complete is "TRUE".

6.3.3.3.6 Battery Design Capacity—Battery_Design_Capacity shall indicate the EV Storage Battery's rated static capacity (C) as confirmed by SAE J1798 using the "constant current method". SAE J1798 specifically deals with individual battery modules. The number C shall be appropriately scaled to represent the number and configuration of the modules that make up the total EV Storage Battery.

6.3.3.3.7 ETS Sleep—ETS_Sleep shall be assigned a value of "TRUE" to indicate that the ETS has concluded the present energy transfer session and that the vehicle may enter a low-power (sleep) mode of operation when the conditions are appropriate, if such a mode is supported. Otherwise, ETS_Sleep shall be assigned a value of "FALSE".

This will be used as a part of the SAE J1850 communication network to stop the transmission of messages from the EVSE. This communication channel must be idle in order for the EV to enter low power mode. See SAE J2293, Part 2.

6.3.4 CONTROL POWER CONVERSION OF ELECTRICAL ENERGY—The purpose of this process is to determine the power level of the conversion process so that the present energy transfer strategy is met, and to determine if the present power stage's power range is insufficient. It is expected that this process will implement some type of closed-loop control of the electrical characteristics of the EV or the EV Storage Battery, such as voltage or current. The exact control method will not be specified, except to describe what outputs are expected.

The exact characteristics that should be considered to control the power conversion will vary based on manufacturers' specific vehicle designs and EV Storage Battery Technology. Therefore, no vehicle- or battery-specific flows are shown into this process.

6.3.4.1 Input/Output Flows—See Table 51.

TABLE 51—CONTROL POWER CONVERSION OF ELECTRICAL ENERGY—INPUT/OUTPUT FLOWS

Flow Name	Type
Min_Stage_Power	Input
Max_Stage_Power	Input
Max_Power_Level	Input
Pulse_Mode	Input
Stage_Index	Input
Stage_Power_Limited	Input
Power_Level	Output
Power_Out_Of_Range	Output
Pulse_Mode_Enable	Output
Pulse_Hi_Period	Output
Pulse_Lo_Period	Output

6.3.4.2 Initialization—The following shall be performed once upon activation of this process: None.

6.3.4.3 Operation—The following shall be performed continually while this process is active:

6.3.4.3.1 Power Level—Power_Level shall be assigned a value less than or equal to Max_Power_Level that indicates the present energy transfer strategy's desired power level of Conv_AC_Electrical_Energy. See 6.1.3.2.

Power_Level shall be assigned a value greater than Max_Power_Level if, and only if, the power level indicated by Max_Power_Level is immediately insufficient to prevent the vehicle and its on-board components from eventual damage or shortened service life. Exceeding Max_Power_Level may have financial consequences for the User due to the cost of energy and agreements with their Utility.

Stage_Power_Limited should be considered when determining if the value of Power_Level should be increased. If power is limited, further increases in Power_Level will have no affect.

6.3.4.3.2 Power Out Of Range—Power_Out_Of_Range shall be assigned a value of "HI" ("LO"), if the present strategy desires a power level of Conv_AC_Electrical_Energy greater (less) than what is available from the active power stage as defined by Min_Stage_Power and Max_Stage_Power. Otherwise, Power_Out_Of_Range shall not be assigned a value.

Stage_Power_Limited should not be considered when determining the value of Power_Out_Of_Range. If power is limited for the present power stage, it may be a temporary condition, and power stages with higher power capability may also be limited.

6.3.4.3.3 Pulse Mode Enable—Pulse_Mode_Enable shall be assigned the value "TRUE", if the present strategy calls for a positive-pulsed mode of operation as described in 6.1.3.4 and the value of Pulse_Mode is "SUPPORTED". Otherwise, Pulse_Mode_Enable shall be assigned the value "FALSE".

If the value of Pulse_Mode is "NOT_SUPPORTED", then the EVSE is not designed to support a positive-pulsed mode of operation. See 6.3.1.4.

6.3.4.3.4 Pulse Period—Pulse_Lo_Period and Pulse_Hi_Period shall be assigned values that indicate the period of the P0 and P1 power phases of the positive-pulsed mode of operation described in 6.1.3.4 if the value of Pulse_Mode_Enable is "TRUE". Otherwise, Pulse_Lo_Period and Pulse_Hi_Period shall not be assigned values.

6.3.5 (SECTION DELETED)

7. System Architecture—There are 3 different system architectures for the ETS that determine how the elements of the functional requirements (see Section 6) are to be grouped into equipment (EVSE and EV) and how that equipment is to be connected. The detailed physical descriptions will be limited to the boundaries between the EVSE and the EV. The specifics of the design within the equipment is left to the manufacturer of the equipment. It is required that the equipment, viewed at the boundaries, functionally act as the combined functional requirements that are grouped within.

System architecture variations shall be referred to as the following:

a. Type A—Conductive AC System Architecture
b. Type B—Inductive System Architecture
c. Type C—Conductive DC System Architecture

The physical interfaces to the external systems will not be described. The specifics are left to the equipment manufacturers. These interfaces are required to provide the data and electrical energy as described in 5.1. When optional external systems are not present or not supported by the equipment, then flows that would be sourced from that system shall be considered to be their defined default value.

7.1 Requirements Allocation—The ETS can be viewed as four (4) groups of functions. These groups are loosely defined as a series of switches, converters, and the logic to operate them, which act to transform AC electrical energy into DC electrical energy as shown in Figure 2. In order to accomplish this transformation, the groups will function together by sharing information.

These functional groups (FG) are not likely to be implemented as separate components. However, this grouping is convenient because it can represent the variation due to different system architectures. Each group will be implemented as a part of a piece of equipment, EVSE or EV, depending on the type (A, B, or C) of system.

The control and process specification elements of the requirements model in Section 6 are each allocated to one of the four groups. Elements are optional or required for specific architectures, as indicated by "O" and "R", respectively. Some optional elements are grouped as follows, and shall be implemented as a group by EVSE or EVs that support the option:

a. O1—Positive-pulsed power mode
b. O2—Voltage control mode
c. O3—LMS Support
d. O4—VS Support

A note will indicate when an option requires the optional serial data channel be implemented for Type A systems.