ARCHITECTURE AND METHOD FOR PROVIDING PRIORITY CHARGING FOR GOVERNMENT AUTHORIZED EMERGENCY ELECTRICAL VEHICLES (AEEV)

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ABSTRACT

The US government predicts more than 1 million electric vehicles (EVs), on U.S. roadways by 2015, and these numbers will increase exponentially in the future. However, the power grid cannot furnish the charging for numerous EVs at a given time mainly because of its energy production capabilities, peak usage, and distribution infrastructure. Some studies indicate that adopting “smart” charging, for example, scheduling EV charging, can alleviate the challenge. Nevertheless, such strategies are not useful for emergency and first responders’ vehicles. This thesis proposes a solution that provides priority treatment for government Authorized Emergency Electrical Vehicles (AEEV). The thesis proposes a complete architecture for providing priority charging service to the government authorized electric vehicles from any utility operator. To realize such a service, this proposal also suggests modifications required in the IEC15118 and IEC 61850 protocol suites. These protocols provide communication between Vehicle and Grid.

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I am indebted to my Family and friends for their support in every aspect of my life.

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ABBREVIATIONS

EV, Electric Vehicle

PEV, Plug-in Electric Vehicle

DOE, Department Of Energy

EVSE, Electric Vehicle Supply Equipment

AEEV, Government Authorized Emergency Electric Vehicle

PCS, Priority Charging Server

IEC, International Electro-technical Commission

FCC, Federal Communication Commission

NCS, National Communication System

V2G, Vehicle to Grid

IEEE, Institute for Electrical and Electronics Engineers

WIMAX, Worldwide Interoperability for Microwave Access

4G LTE, 4^{Th} Generation Long Term Evolution

WAN, Wide Area Network

MAN, Metropolitan Area Network

ISO, International Standard Organization

IP, Internet Protocol

TCP, Telecommunication Control Protocol

AAA, Authentication Authorization and Accounting

PCS, Priority Charging Server

PS, Policy Server

EVCC, Electric Vehicle Supply Equipment

SECC, Supply Equipment Communication Controller

SAE, Society of Automotive Engineers

HLC, High Level Communication

LLC, Low Level Communication

LoWPAN, Low power Wireless personal Area Network

HAN, Home Area Network

WiLAN, Wireless Local Area Network

MAG, Mobile Access Gateway

P-MAG, Portal Mobile Access Gateway

NS, National Security

EP, Emergency Preparedness

MPS, Multimedia Priority Service

GETS, Government Emergency Telecommunication Services

PR, Proxy Router

SR, Serving Router

PLC, Power Line Communication

IETF, Internet Engineering Task Force

UDR, User Data Request

AVP, Attribute Value Pairs

XML, Extensible Markup Language

VIN, Vehicle Identification Number

VI, Virtual Instrument

PMU, Phasor Measurement Units

CHAPTER I

INTRODUCTION

This chapter provides a brief introduction on ‘demand for EVs in future’ and explains the impacts of EV charging on the power grid, it highlights the future projections of EV charging demands. It also emphasizes the ongoing ways to resolve the issues due to EV charging on the power grid and discusses how EV priority charging is important for government emergencies.

Introduction to impact of EV charging on Power Grid stability

The remarkable technology advancements in the consumer automobile industry pioneered the search for the fuel efficient vehicle, which further invigorated the research for developing the efficient Electric Vehicle (EV) technologies. The growth in EV industry augmented with the enhancement in charge retaining capacity of the battery and acquisition of green energy resources. In power utility companies view, when numerous EVs are populated in a particular substation zone it may cause distribution power deficit and alters the stability of the grid. The negative impacts on the power grid because of heavy demand of EV charging is provisioning the research for designing the advanced electric vehicle technologies and the way future power networks are designed and controlled [1]. Moreover, the power generation and transmission utilities will have significance, in determining the capability in realizing the benefits of owning an EV [2]. One of the revolutionary ideas that can be implemented by the utility companies is to use opportunistic charging schemes, which proposes utilization of off-peak, idle generation capacity for the EV charging. These Schemes are efficient in the current dispatch curve, but not palatable with higher growth rates of EVs in the future. The graph in the Figure 1 shows the power usage variation during different times of the day and a typical load curve due to PEV charging.

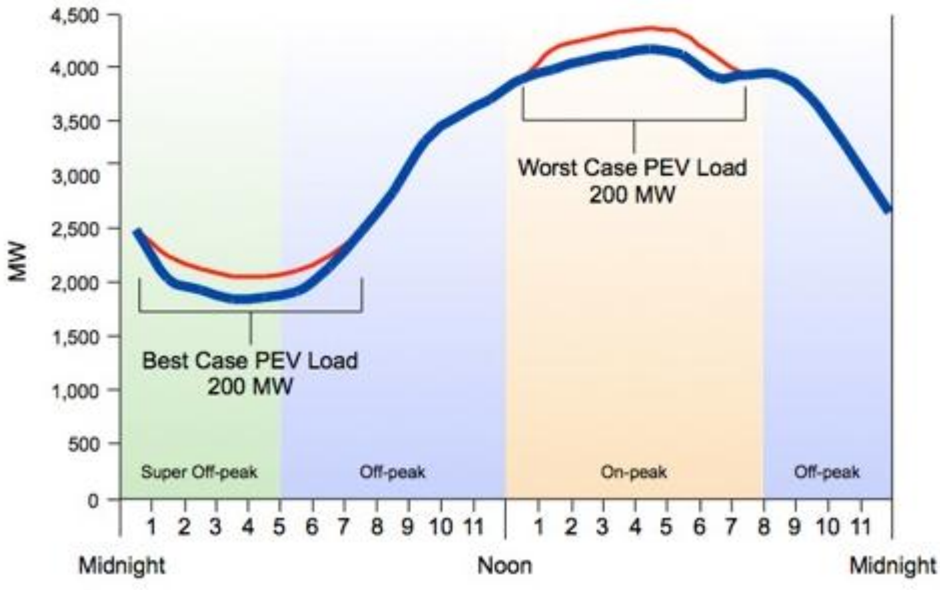

Figure 1 PEV load impact on the power grid [3]

Projections are made that the growth rate in EV numbers will be more than 200% between the years 2012 to 2015, but the annual average growth rate in the electric power supply remains less than 4%, by using these projections an assumption is made that power grid cannot furnish the EV charging needs and also cause power grid failures [4]. This mismatch in the power supply verses consumption ratio may result in the failure of the power systems and raises the issue of grid instability. The graph in the figure 2 accounts for the government projections for the EV numbers on road in the future.

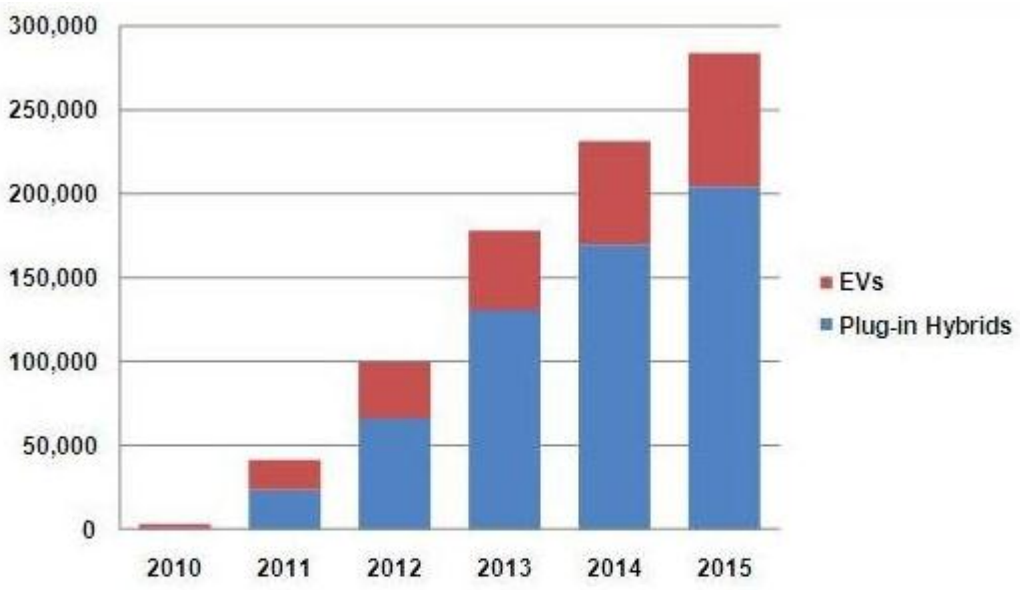

Figure 2 Graph showing future number of EV's on road [5]

Research proposals to ease the EV charging loads

The Department of Energy (DOE) in search of a comprehensive solution for power grid blackouts, due to rise in EV charging demand has endorsed multiple research projects. In these projects a close examination is done on various technical issues involved with the grid stability due to the increase in EV connection requests and proposed several numbers of solutions. Even though most of them are identified as the dependable solutions for eradicating the instabilities in the grid, few hitches are identified in implementation them, which further pioneered the path for research proposals in managing and avoiding the power grid instabilities by building reliable techniques.

Summarizing those researches that can bring significant changes in the future of power grid and EV adoption, the opportunity charging schemes will be foremost and eminent among them, by understanding the power usage behaviour of the consumer, the implementation of smart grid enabled power dispatch techniques can ease the load congestion on the power grid.

One of the ideas that utility companies came up is variable pricing scheme. The utility companies offer the variable pricing to the consumers during the different times of a day, in other words they offer the incentives in usage charges for the customer who charged their EV's during the load off-peak hours of gird. These opportunistic pricing schemes depends on the grid load curve, during the peak hours of load the pricing for usage will be high, which is billed on the bases of per KWh used by consumer and vice versa at off peak hours [5]. The drawbacks of this scheme are; not many users are concerned about the usage charges, most of the users prefer to charge their EV's according to their convenience, these variable scenarios proved potentially damaging to the grid.

There are few other notable researches that can be implemented for avoiding the grid tripping because of EV charging loads; The vehicle to grid application scheme was put forth for avoiding the heavy loads on the grid. It is a policy of exchanging the electrical energy between the EV and power grid. When the electric vehicle is plugged for charging, its battery will be charged during the off peak hours and energy from the same battery is used for accommodating the energy needs of power grid during the peak load period, which will not only drain the EV battery, but also reduces the lifespan it. This method has not proved as the reliable approach for the issue in terms of equipment protection and sustainability [5].

Considering these all the techniques to reduce load on the power grid due to the raise of EVs, a conclusion is drawn, that the there is no comprehensive solution for the grid load issue. If the power grid cannot provide the charging for the public vehicles in the future, imagine the situation of the government vehicles that are involved in the emergency operations. A standard conceptual method is emphasized in the priority charging system that will provide solutions to overcome the load issues and provide the instantaneously charging for the emergency vehicles. The priority Charging technique in simple is the integration of the telecommunication operations, smart sensor networks with power sector to manage the distribution of power, without any instability.

Overview of the concept

To mitigate the widespread severities on power management sector, many studies suggest adopting “smart” charging strategies, so that average EV load does not exceed the peak of power usage load. Such schemes fall into three categories: effect of time-of-use rates [6], coordinated charging scheduling [7], [8], [9], and decentralized scheduling [10]. To that end, the EV charging initialization protocols are embedded in the intercommunication signals between the Electric Vehicle Supply Equipment (EVSE) and the power grid. These protocols serve several objectives including intercommunication and scheduling the most appropriate time for complete charging of the vehicle.

Adoption of “smart” charging strategies and broadcasting incentives or price profiles may help utilities manage the grid resources, power production capabilities, and distribution infrastructure to cater for the general public. However, these options are neither feasible nor desired for Government Authorized Emergency Electrical Vehicles (AEEV) as these vehicles require priority treatment to combat emergency situations.

This thesis proposes a complete architecture and a method to get the priority charging service from any utility operator. One of the key elements of the proposed architecture is the Priority Charging Server (PCS); a database to register and maintain the AEEV ID’s and their assigned corresponding priority levels that will be used to authorize the AEEV prior to setting up a charging session. Furthermore for the realization of the complete solution, it also proposes modifications in the IEC15118 and IEC 61850, the communication enabler protocols between Vehicles and Grid.

It is worth mentioning that priority services also exist in telecommunication domain, where government authorities and first responders are given priority to use radio and network resources in case of manmade disasters (terrorism) or natural disasters (hurricanes, floods, earthquakes etc.). The notion of priority services has been successfully implemented in the telephony arena, where the Federal Communication Commission (FCC) program directs telecommunications service providers to give preferential treatment during the disasters and emergency conditions to government organizations enrolled in the program; and the National Communications System (NCS), a part of the U.S. Department of Homeland Security, manages the program. However, the concept of Priority Recharging of EVs has not been developed yet. Therefore, it is a primary object of the present thesis is to provide a system, method and architecture to provide priority charging treatment to the AEEV.

In the preceding chapters, an in depth explanation for the priority charging and concepts for implementing it are discussed. A simulation model is developed and executed to demonstrate the possibility for practical implementation of the priority charging method.

CHAPTER II

VEHICLE TO GRID COMMUNICATION

This chapter follows with the explanations about communication interface between the electric vehicle and the power grid (V2G) and further discusses about the research advancement made in V2G communication. A data management network infrastructure is depicted to provide the comprehensive view of V2G communications. The specifications of EVSE, which plays a preeminent role in the data and power management, are enlisted, with detailed inter-functions takes place in EVSE. Standard protocols that are used in V2G front end and back end communication are emphasized.

Vehicle to Grid (V2G) Communication

The term V2G represents an interface between the electric vehicle and power grid. The synchronization of electric vehicle charging with the power grid delivering capability is the orientation for deploying V2G communication system. V2G communications can perform multiple operations to acquire the real time data from the user vehicles. It is necessary to develop and maintain a reliable V2G communications network, to avoid the interruptions in power supply and fault eruptions in electric vehicle battery at the time of charging. The critical tripping faults can be avoided in the grid by the installation of ubiquitous V2G communication system.

The vehicle to grid communications plays a vital role in user interface with the electric grid and utility company. It also involves the process of notifying the user about power usage charges, billing data and EV battery charging levels. In communication with the grid database, both vehicle specific data with the technical standards of the battery (capacity of battery, interoperability) and location related details are transmitted to the utility for establishment of consistent charging session. In compliance with the power grid's load handling capacity, the V2G communication enables the load dispersion by scheduling the EV charging to off-peak hours.

To maintain a substantial power connection between to the EV, it is important to install low loss communication networks, as the power connection to EV is controlled by the commands received via communication networks. Although various communication networks can be used in connecting V2G, most of their performances and efficiencies vary depending on factors like service location and environmental conditions, for example, a wireless communication network operated in a metropolitan area may not prove scalable communication source for the V2G as it might undergo congestion due to the heavy voice and data traffic. Considering the feasibility, ease of deployment and cost of deployment, preferential network selection is done among wired communication networks (power line communication, optical fiber cable), or for long distance wireless communication. The networks used in V2G communication must have reliable data transferring capacities and must ensure the quality of service at any given point of time. There are several technical specifications that a communication network must be qualified in order to be considered as qualified network for V2G communication. The communication networks like LTE, WiMax, optical fiber networks, etc are declared as competent networks for V2G communication.

The communication protocols that are used in V2G communications are IEC15118, IEC 61850 and IEC 61851-1,2,[11] which are set by international Electro-technical committee (IEC)/ International standards organization (ISO); these protocols are widely arbitrated by ISO because of their network backward compatibility (support both IP V6 and IP V4 network stacks) and assurance in triggered data transfers. In this system, both of the standard protocols IEC 15118, IEC61850 adopt TCP/IP protocol stacks format for optimal performance in the network.

Electric Vehicle Supply Equipment (EVSE)

EVSE is the hardware/software interface for communication exchange between EV and power grid, it even contains the power controller switch to enable/disable the power supply. The Supply Equipment communication controller handles the data that is exchanged between EV and power grid operations database. V2G front end communications takes place between Electric Vehicle Communication Controller (EVCC) and Supply Equipment Communication Controller (SECC); these communication controllers are responsible for the generation of requests and reply messages between EV and EVSE and also routing the commands to the internal hardware of the devices, using IEC 15118 protocols and the back end communication is between SECC and database using IEC 61850 protocols [11], justifications for choosing IEC 61850 protocol are discussed in chapter 4. SECC is obligated for establishing the secure data connection for the synchronization of user authentication data and charging status data at regular intervals between EV and database.

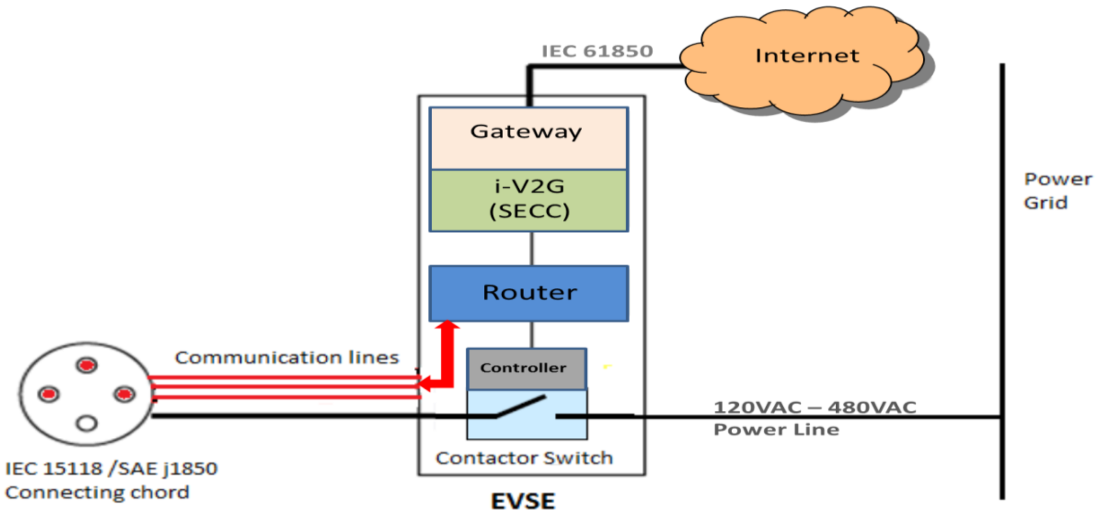

Figure 3 Internal blocks of EVSE

EVSE executes the commands received from the grid operations controller and further directs them to sub-processing switching mechanisms. SECC transmits the data through a dedicated gateway capable of making the communication tunnelling to the database for the lossless transmission. EVSE is responsible for collecting the following data parameters about EV during various events of charging [12].

Event:

1. Unique ID for Plug-in Event - (server action “connected ticket”)
2. Unique ID for Charge Event(s)- (server action “billing cycle ticket”)
3. Unique ID Identifying the EVSE – Hardware ID
4. Unique ID for the vehicle being charged (battery status report)

No user specific information is required to initialize a connection with the EVSE. An advanced EVSE device is also capable of registering the timing information (Timestamp data) for user notification (in traditional EVSE, timestamps used to be recorded in the datacentre). The EVSE will register the following events in the operations database

1. Vehicle Connect Time (Start of the Plug-in Event)
2. Vehicle Disconnect Time (End of the Plug-in Event)
3. Charge Start Time (i.e. Time stamp when EVSE begins to transfer power)
4. Charge End Time (i.e. Time stamp when EVSE stops transferring power)
5. Average Power (AC kW) per charging event
6. Total Energy (AC kWh) per charging event
7. Rolling 15-Minute Average Power (AC kW, captured for each 15-minute interval)
8. Rolling 15-Minute Peak Power (AC kW, captured for each 15-minute interval)

All Time Stamps registered in EVSE are defined in a year month/day/ hour/minute/ second format at the time of charging event, these timestamps are recorded in the grid database and later sent to user devices for the notification [12]. An EVSE will be having the mechanism to decode these timestamps for displaying it in user local time zone. The charging level and battery temperature data is collected by EVSE at an interval of 50 milliseconds and logged to the grid operations database for monitoring the event for every 2 seconds. Depending on the type of carrier and protocols used the data logging interval may change. This data must be securely transmitted via a wireless method to a centralized database.

Management of communication networks in V2G

EV communication data pass through various network topologies, but it uses standard TCP/IP protocols used throughout the communication, because of interoperability and built in error control and flow control mechanisms offered by TCP/IP protocols , they ensures the reliable transmission of data. The basic information data flowing between EV and grid operation controller unit is segmented in two phases.

Phase 1: Communication initialization:

When an EV and EVSE are connected, a communication link is established between EVCC and SECC, which uses the standard IEC 15118 protocol. This connection is made using the physical chord that can transfer both electricity and communication signals; these chords are usually manufactured by using the hardware standards like SAE J1772 [13]. The typical model of SAE J1772 has three mini pins for communication interchange between EV and EVSE and one or two main power supply pins; the number power supply pins vary with the battery capacity (1 power pin for 240 VAC, 40 amp, 3KW battery and 2 pins for the batteries ranging between 10 KW to 480 VAC, 85 amps 60KW).

The communication controllers embedded in EV and EVSE are responsible for initializing the high level communication (HLC) for accelerated transmission of data. Low

Level Communication (LLC) protocol is used for safety critical system operations, for notifying the state changes due to connection losses or state change of the battery charge level. After the initializing handshake signals between the controllers, the EVCC starts transferring identification information (EV hardware ID) and authorization details (user permissions to use power connection) to the SECC. The SECC bundles the IP address, port specifications and EV information for sending a request to grid operations data base, which either resides under the possession of utility company operations unit or at third party networking services provider. The database verifies the EV identity number and usage authorization and replies an acknowledgement message to SECC. Now, SECC starts gathering the battery status information from the EVCC for calculating the time required to charging the battery to its maximum capacity.

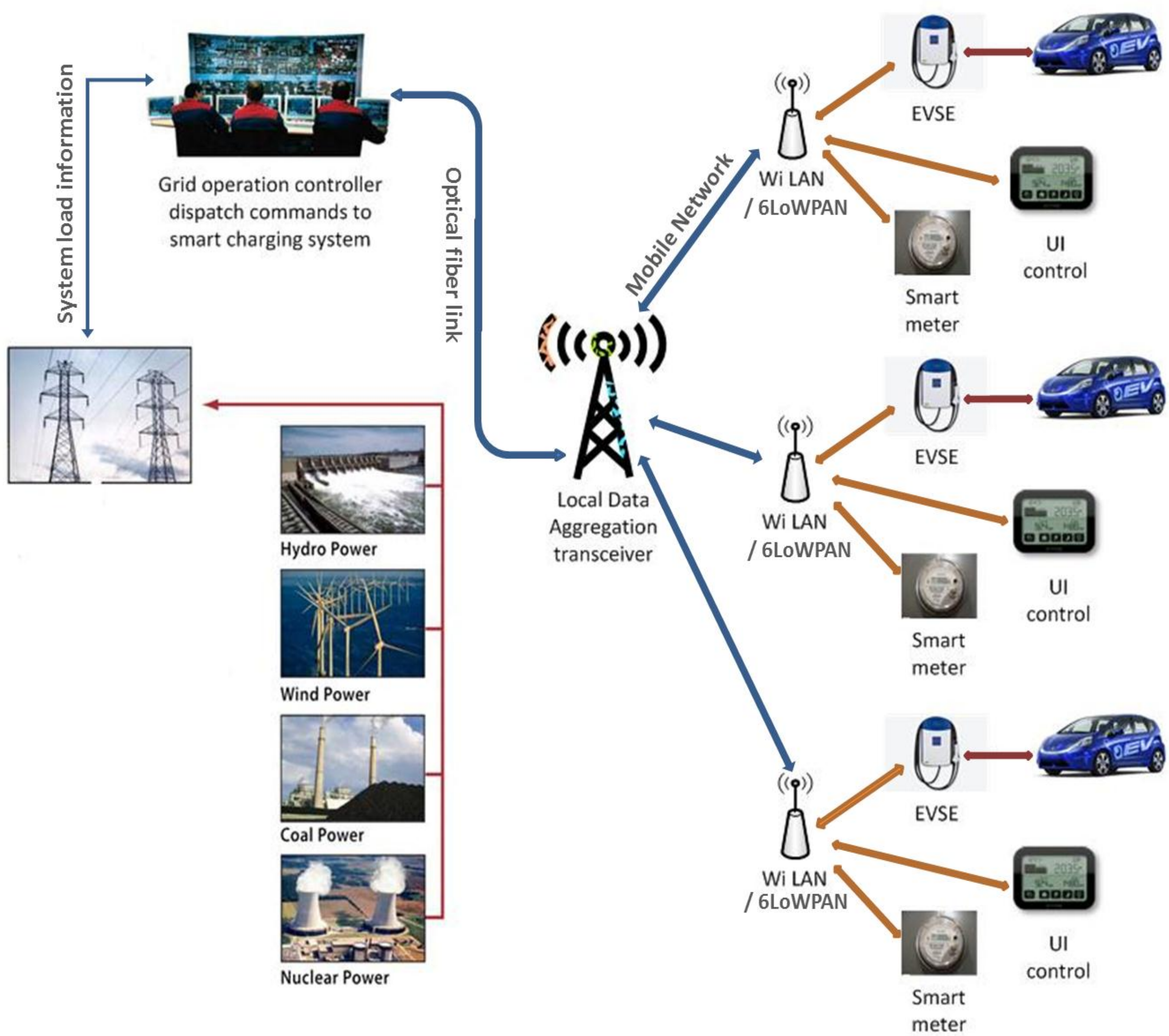

Figure 4 Comprehensive picture of network communication in V2G

Phase 2: Connection management through the networks:

Communication between the SECC and grid operation controller involves two types of networks; the first network is used for local intercommunication between the EVSE, smart metering unit and user status display devices. There are various wireless networking options available for integrating the user interface devices with EVSE for information exchange and notifications with in the local range, widely recommended among them are Low power Personal Area Networks (LoWPAN) and zig-bee network. As we have already discussed that by default TCP/IP protocols are followed throughout communication process, which supports the inter-network operations. When an EV is connected to EVSE, EVSE gets access to all the hardware and software information of EV. This phenomenon will simplify the communication process in the network by reducing the number of hops in transferring the data because the authorization data will be stored in EVSE until the charging session is terminated. The PAN provides wireless integration between EVSE, smart meter and user devices. Smart meter gathers the power usage (KWh) information from EVSE in regular periods to calculate the usage cost, which can even be further accessed by the user interface device. This criterion helps the user to get aware of usage charges. EVSE also notifies the user devices about the battery status using PAN.

These PAN / HAN is connected to the grid operations servers through advanced mobile networks (LTE). The data received from multiple local networks(PAN/HAN) is collected and forwarded to grid operation controller via an optical fiber communication link at a higher frame rates by the data aggregation transceiver (mobile network Base station). The data from grid operations controller disperses to the local network ports from the transceiver as shown in the above figure.

The grid operations controller collects power systems load information to make decisions on the allocation of charging to the EV. During the normal load conditions, the EV charging will be enabled instantaneous after the charging request has been made, but during the peak load time a queue scheduler is enabled which postpones the EV charging to a later time.

Encapsulation of Data Packet in V2G Networks

V2G networks are structured for sending the hardware Id, IP address and port information, which is substantial for grid database for spotting out the EV location, these location indices are collected to compare the substations load at the request location. The data packets in V2G are enclosed with EV hardware information, battery status and control commands. The low power personal area network has the routing algorithms. These routing algorithms are used in directing the packets through the special gateways specifically designed for secure data transmission.

The packet data encapsulation in V2G network takes place in the network layer. The data is encapsulated with the source IP address; it uses IP version 6 format and has global and local network identification variables. The network layer encapsulates the packet, with Portal Mobile Access Gateway (P-MAG), which is used for controlling the security and application properties in the mobile networks. The MAG plays an important role, while sharing the data through the infrastructures of mobile networks. The routing tables are programmed in the network layer for transferring data through secure tunneling path (Sec Path) to the database using the mobile networks. The control information in P-MAG is used for managing the application policies and visibility of application in the mobile network, in most cases the application is only set to be visible to the destination address [14]. The packet data encapsulation stacks in V2G communication are shown in the figure 5.

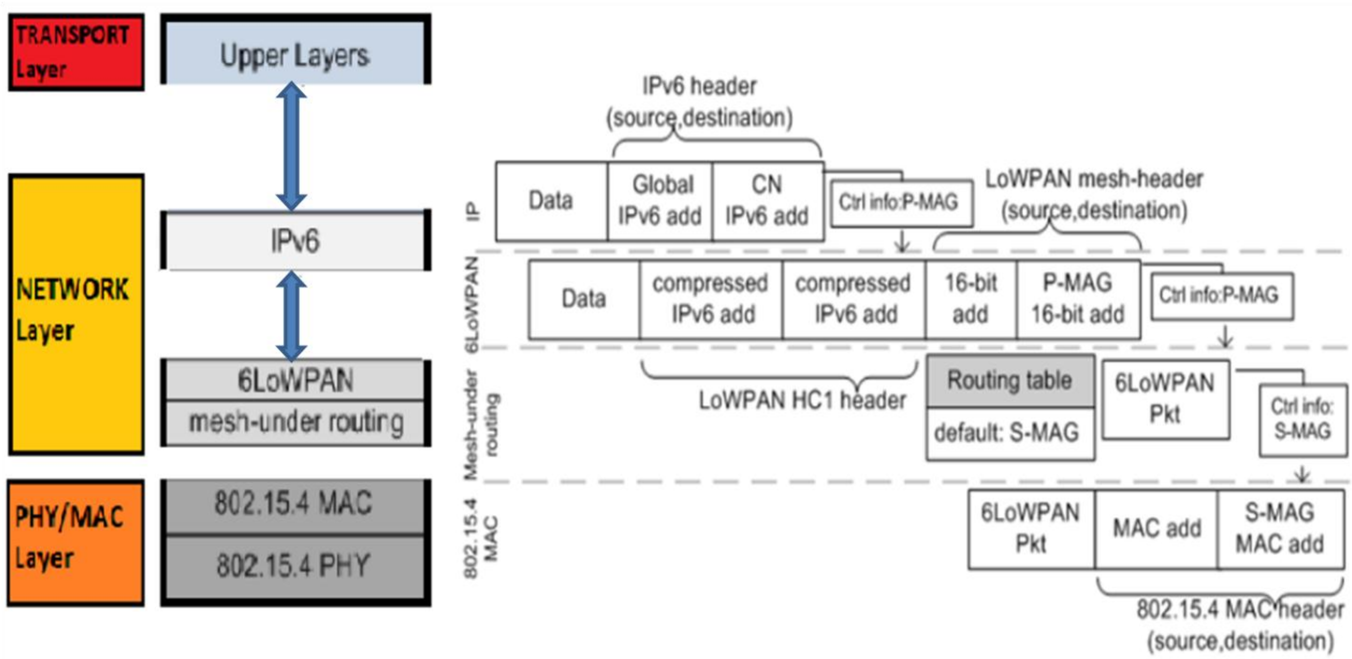

Figure 5 Encapsulation of data packet in V2G network in contrast with OSI layers [14]

Concept of Priority Services in Telecommunications

Traditional telecommunication network during the disasters or crises is a fiasco because of strain in the network. To overcome this issue, certain class of subscribers and government entities are made capable for accessing the scarce network resources by allocating the priorities. These priorities cater the government organizations to connect to public emergency and safety agencies. The priority services in communication were used in Telecommunication industry for providing the uninterrupted communication services to the government authorities and public service coordinators in case of emergencies and nature disasters. The priority services in telecommunication systems were introduced by the federal government, the National security / Emergency preparedness (NS/EP) are responsible entities for regulations and operations. All the telecommunication carriers must provide the priority services under the jurisdiction of FCC. Multimedia priority service (MPS) allows authorized users to gain access to the radio resources on the priority basis.

In the process, of setting up a priority session, the user does not need to use any special codes of identification for the authentication or authorization purpose; perhaps it's the network task to identify the priority user by examining the priority database values. These priority database values are predefined at the time of EV registration and used for authenticating the user priority. A priority driven connection should be capable of invoking priority sessions for all the applications that are supported by the network (Voice and data) [15]. The priority session will receive priority radio treatment for voice and data channels in terminating normal operations on mobile network when the session is originated by the priority user. During a critical congestion, when a priority user encounters a "no resource available" condition the session will be queued and to be processed with next available radio resources depending on the level of priority Similarly, in the case of data services the priority reservations for the data to reach the service user is done by priority admission and retention of packets in the IP flow through a secure protocol interaction with the network [15].

CHAPTER III

PROPOSED ARCHITECTURE AND METHOD FOR PROVIDING PRIORITY CHARGING EV

This chapter explains about the idea of priority charging and gives the details about communication process involved in priority allocation. In order to describe the priority assignments for various types of vehicle a priority allocation catalog model is provided. The proposed architectural block diagram elaborating the hardware and software components involved in the priority charging is explained.

EV charging priorities

Before specifying about the implementation of priority services in EV, it is worthy to mention about the previous researches that have induced an idea of EV priority charging [16], Maël Cazals and Gilles Vidalenche discussed the priority where the fleet manager manages EV charging priority. But, the priority scope, priority strategy, and priority criteria are completely different. The priority scope is local i.e. assigning the priority to certain fleet vehicles within the company. The priority strategy is manual i.e. Defined, implemented and managed by the fleet manager (a person) in the company, and priority criteria is that from among the entire company's fleet, only subset of the vehicles whose battery level is minimum and are intended for company's urgent interventions will be charged on priority basis. The criteria also takes into account factors such as tariff bands, available power, and reservation slots booked by the drivers.

In contrast to above noted work, the spirit of this thesis work is completely different.

It involves Priority Charging Server (PCS) that resides in the network. PCS would register and maintain the database of AEEVs credentials (such as AEEV's ID's and their assigned priority levels). Upon invocation of priority charging service request by an AEEV, the service providing grid, prior to setting up a charging session between the grid and EVSE, would first ask PCS to verify AEEV's credentials. Upon authentication, the priority service would be provided by the utility. The grid would also have the option to preempt the ongoing charging sessions, or downgrade the charging levels of ongoing charging sessions, depending on the available grid/distribution resources, to endow with priority to the AEEV. The priority criteria and priority levels would be assigned and administered by the government authorities at some centralized or distributed PCS. To realize the priority service, modification in the existing protocols is needed. The solution also introduces modifications in the IEC15118 and IEC 61850 protocol suit that enables communication between V2G.

The Proposal

In case of emergencies and disasters, the available power resources may be limited, or their transmission/distribution may be crippled due to catastrophe, whereas the demand at such instances may shoot up. Under such circumstances power grid may not accommodate the charging of numerous EVs (general public vehicles, as well as emergency response and management vehicles) at a time. It is therefore, imperative that under such situations priority treatment be provided to the emergency response and management vehicles. Thus, a system, method and architecture are proposed to address this issue.

Communication Process with Priority Charging

Figure 6 shows the V2G communication process where priority treatment is provided to the AEEV.

The notion of Priority Services presented in this thesis work is similar to the one in Telecommunications, where a group of people (government people or top-level people) are given priority to use radio and network resources for communication purpose on a priority basis in case of man-made disasters (terrorism) or natural disasters (hurricanes, floods, earthquakes etc.). Thus, even when the network is congested, the authorized personnel can still get access to the network resources to carry out mission critical communication. The priority communication model has been successfully implemented and managed by National Communications System, a part of the U.S. Department of Homeland Security. The concept of Priority charging service may be directed by DOE (Department of Energy), where utility companies will be mandated to give preferential charging treatment to AEEV enrolled in the program.

AEEV would be assigned one of five priority levels (with one being the highest priority level and five being the lowest priority level). It is in synch with the priority levels used for Government Emergency Telecommunications Services (GETS) which are explained in the table 1 [17].

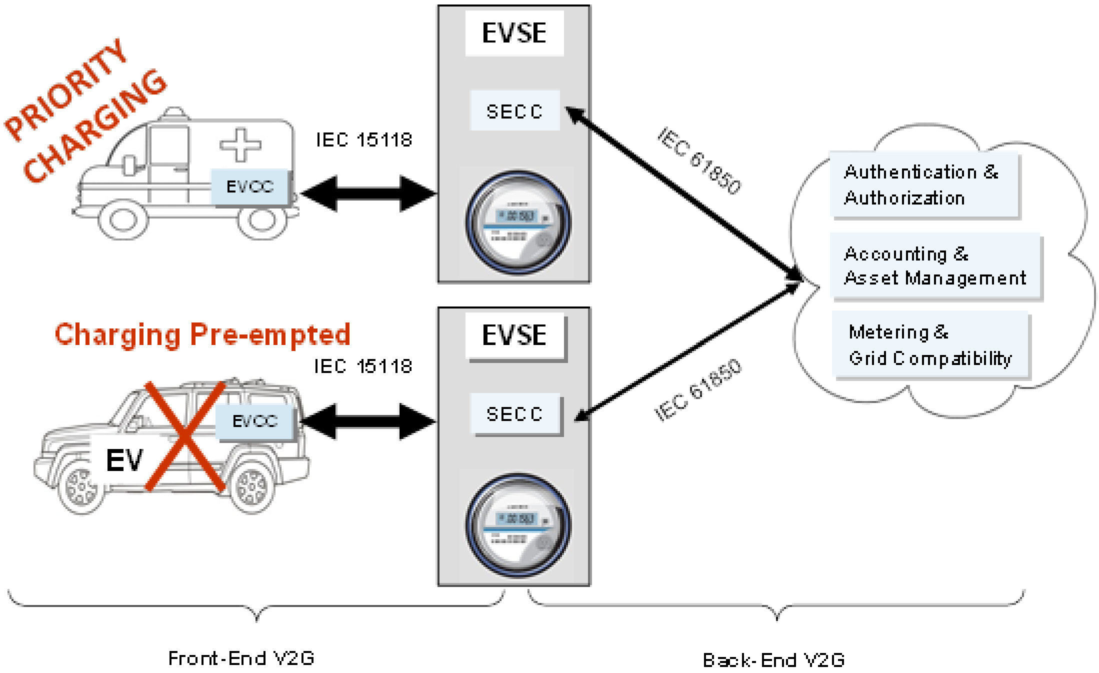

Figure 6 Communication process with proposed priority charging

Priority levels

Table 1 Priority Allocation catalog

Priority Level	Responsibility	Qualifying Criteria
1	Executive Leadership and Policy Makers	Users who qualify for the Executive Leadership and Policy Makers priority will be assigned Priority 1. A limited number of Service Provider technicians who are essential to restoring the Service Provider networks may also receive this highest priority treatment.
2	Disaster Response/Military Command and Control	Users who qualify for the Disaster Response/Military Command and Control priority will be assigned Priority 2. Individuals eligible for Priority 2 include personnel key to managing the initial response to an emergency at the local, State, regional and Federal levels. Personnel selected for this priority should be responsible for ensuring the viability or reconstruction of the basic infrastructure in an emergency area. In addition, personnel essential to the continuity of government and national security functions (e.g., conducting international affairs and intelligence activities) are included.
3	Public Health, Safety, and Law Enforcement Command	Users who qualify for the Public Health, Safety, and Law Enforcement Command priority will be assigned Priority 3. Eligible for this priority are individuals who direct operations critical to life, property, and maintenance of law and order immediately following an event.
4	Public Services/Utilities and Public Welfare	Users who qualify for the Public Services/Utilities and Public Welfare priority will be assigned Priority 4. Eligible for this priority is those users whose responsibilities include managing public works and utility infrastructure damage assessment and restoration efforts and transportation to accomplish emergency response activities.
5	Disaster Recovery	Users who qualify for the Disaster Recovery priority will be assigned Priority 5. Eligible for this priority is those individuals responsible for managing a variety of recovery operations after the initial response has been accomplished.

Architectural Block Diagram and its Description

In order to enable priority charging server, the proposed architecture shown in Figure 7 consists of the following functional entities.

- Priority Charging Server (PCS)
- Proxy Router (PR)
- Policy Server (PS)
- Serving Router (SR)
- Authentication, Authorization and Accounting (AAA)

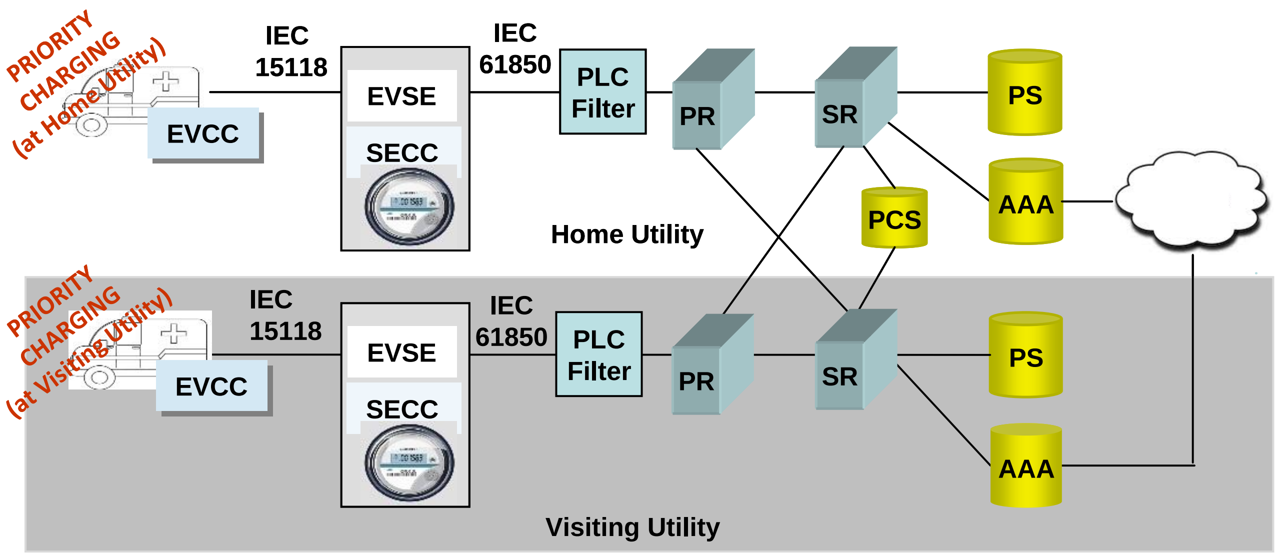

Figure 7 Communication process with proposed priority charging

Priority Charging Server (PCS)

PCS is a database server that contains the EVIDs and the corresponding priority levels that specify the charging privileges associated with each EVID. Upon invocation of priority charging service request by an AEEV, the service providing grid, prior to setting up a charging session between the grid and EVSE sends a query to PCS for AEEV's credentials verification and service authorization. Upon authentication/authorization, the priority charging service is provided to the AEEV by the utility. The grid would also have the option to preempt the ongoing charging sessions, or downgrade the charging levels of ongoing charging sessions, depending on the available grid/distribution resources, to endow with priority to the AEEV. The priority criteria and priority levels are assigned and administered by the government authorities, and maintained at PCS, which may be centralized or distributed.

If the AEEV is in its home utility network, the priority request will be routed to PCS from the home network. This requires two-step authorizations/authorization. First from the AAA (residing in the home network) for the validation of the subscription credentials for billing purpose, and the second from the PCS for the validation of Priority request. If the AEEV is not in its home utility network, and is accessing from a visiting utility network, priority request may be routed to PCS from the visiting network to the home network. This also requires two-step authorizations/authorization. First from the AAA (residing in the home network) for the validation of the subscription credentials for billing purpose, and the second from the PCS for the validation of Priority request. Messages exchanged between these entities can be realized using established IETF protocols such as the Diameter by sending User-Data-Request (UDR) message with the subscription information returned via the User-Data AVP of the corresponding UDA message [18].

If the requesting AEEV is authorized, the PCS applies priority treatment and includes priority marking(s) in the message returned to the Utility AAA. These marking(s) are maintained in all subsequent messages, resulting in associated priority treatment.

Authentication, Authorization and Accounting (AAA)

AAA as the name indicates is responsible for Authentication, Authorization, and Accounting. The authentication/authorization process is initiated when AAA receives an authentication request. This request may be generated by a regular EV or by AEEV. Upon authentication and authorization, AAA sends a message to EVSE to lock the line and initiate battery charging. Upon receiving acknowledgement that the line is locked, and battery charging is started, it receives information (start time end time, etc.) for billing purpose.

Proxy Router (PR)

The proxy router (PR) is the entry point to the network. The EVID is sent through the PR in a secure connection for the verification in the database. The PR is located in the Home Utility Operator as well as at the Visitor Utility network. The PR, simply, handles the battery charging session related signaling in the same way as the PCSCF handles control plane signaling in IP Multimedia Subsystem.

Policy Server (PS)

The policy server is a part of the network architecture that aggregates information to and from the network entities and utility operational support systems in real time, supporting the creation of rules and automatically making intelligent policy decisions for each subscriber who is charging the EV/AEEV.

Serving Router (SR)

The serving router is a node which is responsible of providing routing services between proxy router and all other nodes (such as PCS, PS and AAA). It also enforces policies of utility operator.

CHAPTER IV

EV PRIORITY PROTOCOLS

This chapter of the thesis is organized as follows: Sections 4.1 provides an overview of communication protocols that are segmented in the front end and back end processing. The EV priority protocols are explained with sequence of messages communicated by the front end and back end in sections 4.1.1 and 4.1.2. Section 4.2 contains the modifications that are proposed for IEC 15118 and IEC 61850 to support the priority allocation. The EV priority charging under the various location based usage scenario are explained in section 4.3 and 4.4.

EV Priority Protocols

There are three main entities involved in V2G communication; i.e. The EV, the EVSE and the AAA (Authentication, Authorization and Accounting) server residing in the grid, as shown in figure 8. The EVSE supplies electric energy for EVs. The AAA server handles the authentication, authorization, accounting [11].

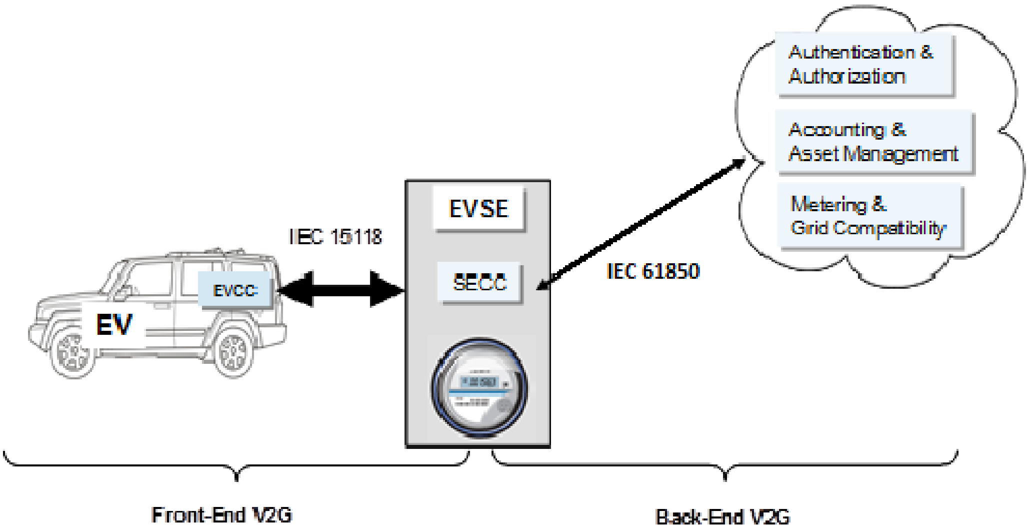

Figure 8 V2G communication process with proposed priority charging

The EVCC (EV Communication Controllers) and SECC (Supply Equipment Communication Controllers), as the names suggest, control the communication between the EV and the EVSE. The SECC also handles the communication between the EVSE and the AAA Server. The communication process, shown in figure 6, can be divided into two parts:

- V2G Front-End Communication and
- V2G backend Communication.

V2G Front-End Protocol

The V2G front-end part carries communication between the EV and EVSE. The existing candidate protocols for the front end communication are IEC-15118, IEC-61851, IEC-62196 and SCCPS [11]. However, ISO/IEC Joint Working Group-15118 defined ISO/IEC-15118 for V2G interface, and hence we chose it to propose a modification in it for priority service realization. The protocol is based upon Power line Communications (PLC) and supports both IPv6 and IPv4. In ISO/IEC-15118, the V2G messages have two main parts: the body and the header as shown in figure 9.

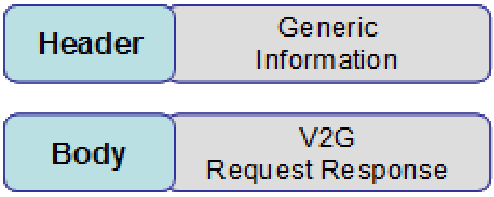

Figure 9 V2G Message format

The header contains generic information such as session ID and protocol version, and the body contains request/ response messages between the EV and EVSE as shown in Figure 10 [19].

The specifications that made IEC/ISO 15118 protocol most appropriate for using in EV to EVSE communication are

- The ISO/IEC 15118 messages will be extended as needed for the implementation of PowerUp use cases [20].
- In ISO/IEC 15118, the operations loop consists of the status and receipt messages, which need to be extended for an adaptive power control [20].
- ISO/IEC 15118 consists of dedicated communication slots for the uninterrupted communication between EV and EVSE during charging session.
- ISO/IEC 15118 are specifically designed for maintaining the power control, communication data, timing information and charging status information.

Below is the explanation for the message interchange between these two entities.

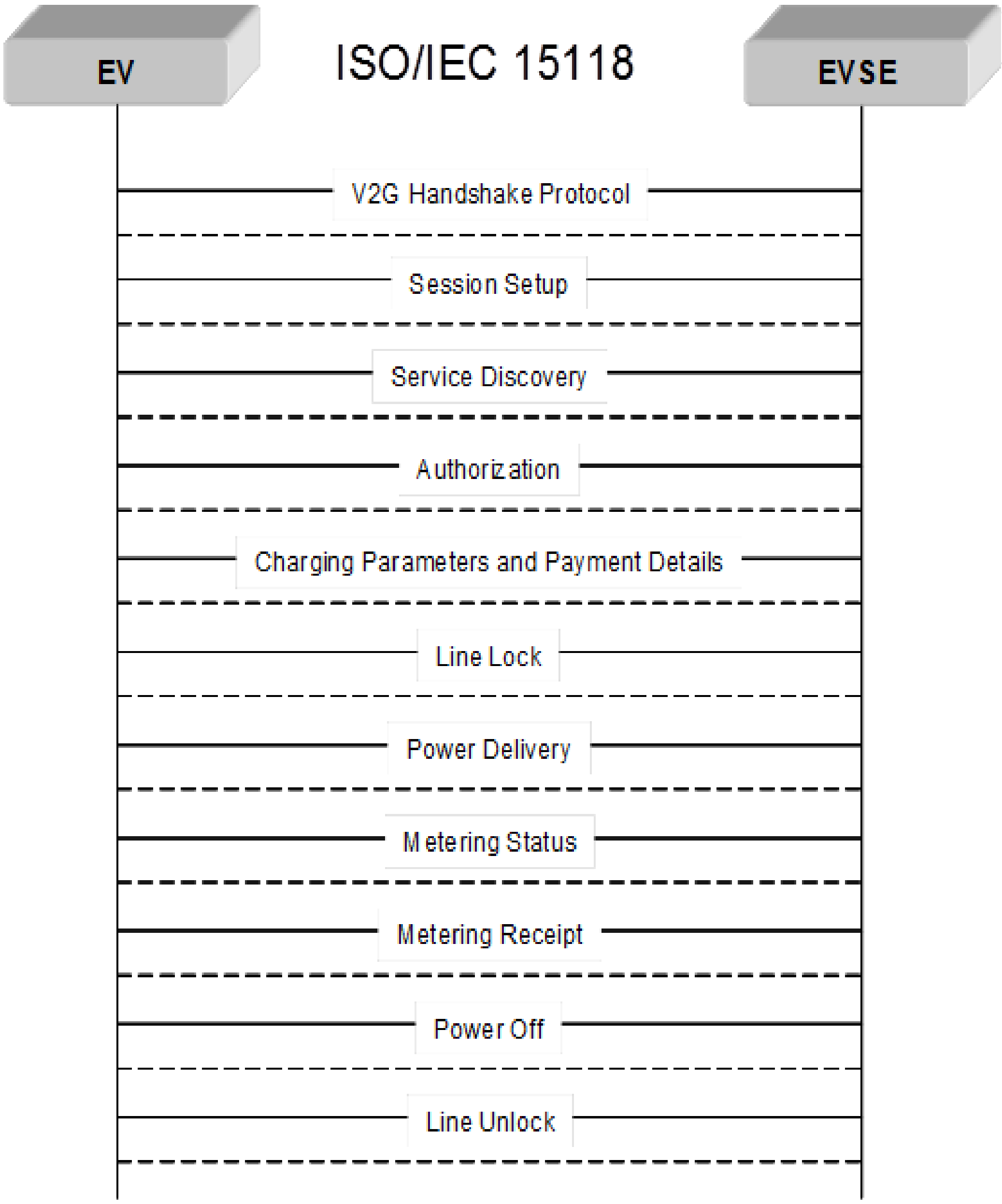

Figure 10 Sequence diagram of V2G message for ISO/IEC 15118 [14]

- V2G Application handshake: Identifies the application layer protocol (e.g. The Protocol version).
- Service Discovery: Discovers available services, (e.g. Charging, value-added-services)
- Authorization: EV provides credentials and EVSE response notifies the EV about success/failure of the authorization.

- Charging parameters and payment details: Exchange of general charging parameters such as EV-charge status, estimated required energy amount and charging duration. The EVSE reply includes applicable grid limits as well as list of available tariffs.
- Line Lock: used to lock the connector on the EVSE side to prevent unintentional removal.
- Power Delivery: After successful authorization the EV requests for switching on of power and confirms the charging profile.
- Metering Status: used to receive meter reading, meter-ID, and maximum output power from the EVSE.
- Metering Receipt: EV acknowledges and digitally signs the meter reading values used in billing.
- Power off: EV requests to stop power supply to EVSE. It is confirmed by the response message
- Line Unlock: unlocks the connector on the EVSE side. Upon receipt of a successful response, the driver can unplug the charging cable.

Figure 11 shows the protocol stack for the TCP/IP Stack for ISO/IEC 15118. As shown in figure, V2G messages have the format of Efficient XML Interchange (EXI) which is an enhanced version of XML (Extensible Markup Language) to improve the performance of computational resources [21].

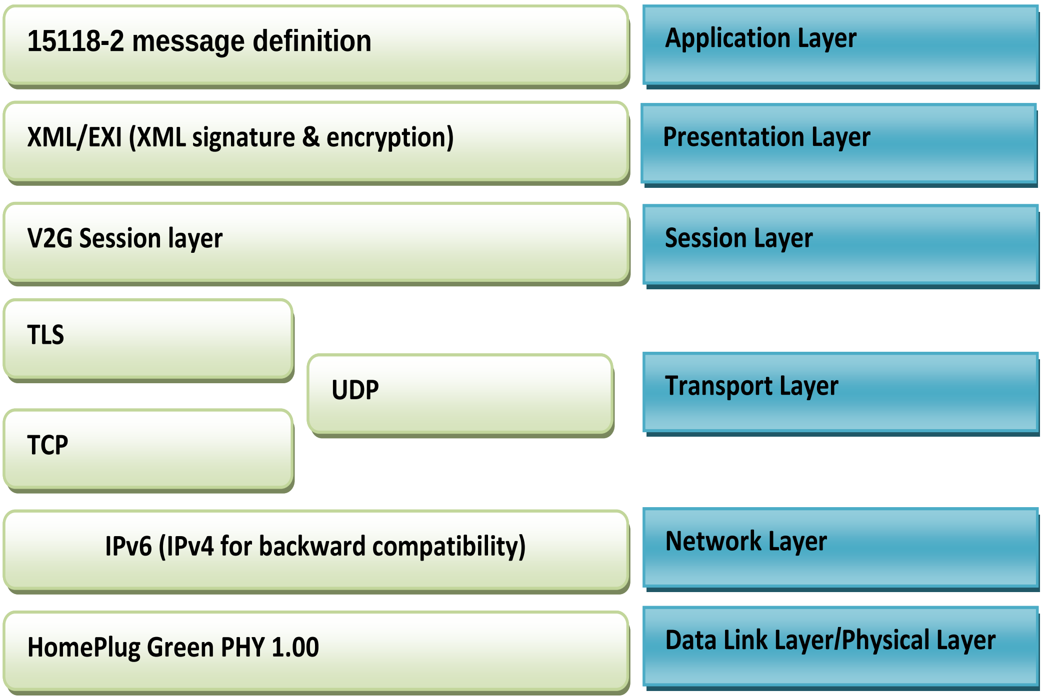

Figure 11 TCP/IP stack for ISO/IEC 15118

V2G backend Protocol

The V2G back-end protocol is IEC 61850 that governs the communication between the EVSE and AAA Sever. Figure 12 shows the mapping between the front-end and the backend protocol messages. These messages are listed as follows:

- EV sends power discovery request to EVSE
- EVSE sends a report to Utility AAA (containing the requested power demand, time frame information and the charging capabilities)
- In response, the Utility AAA sends set data values request which instructs the EVSE to set the values of the charging schedule and then the EVSE sends the power discovery response to the EV.
- After receiving the power discovery response, the EV sends the power delivery request to the EVSE which sends the set data values response to the Utility AAA.
- The EVSE sends the power delivery response to the EV which will initiate the

charging process.

- When the charging process ends, the EV sends a power off request to the EVSE which sends a concluding report containing the charging information to the utility AAA.
- EVSE sends Power off response to the EV.

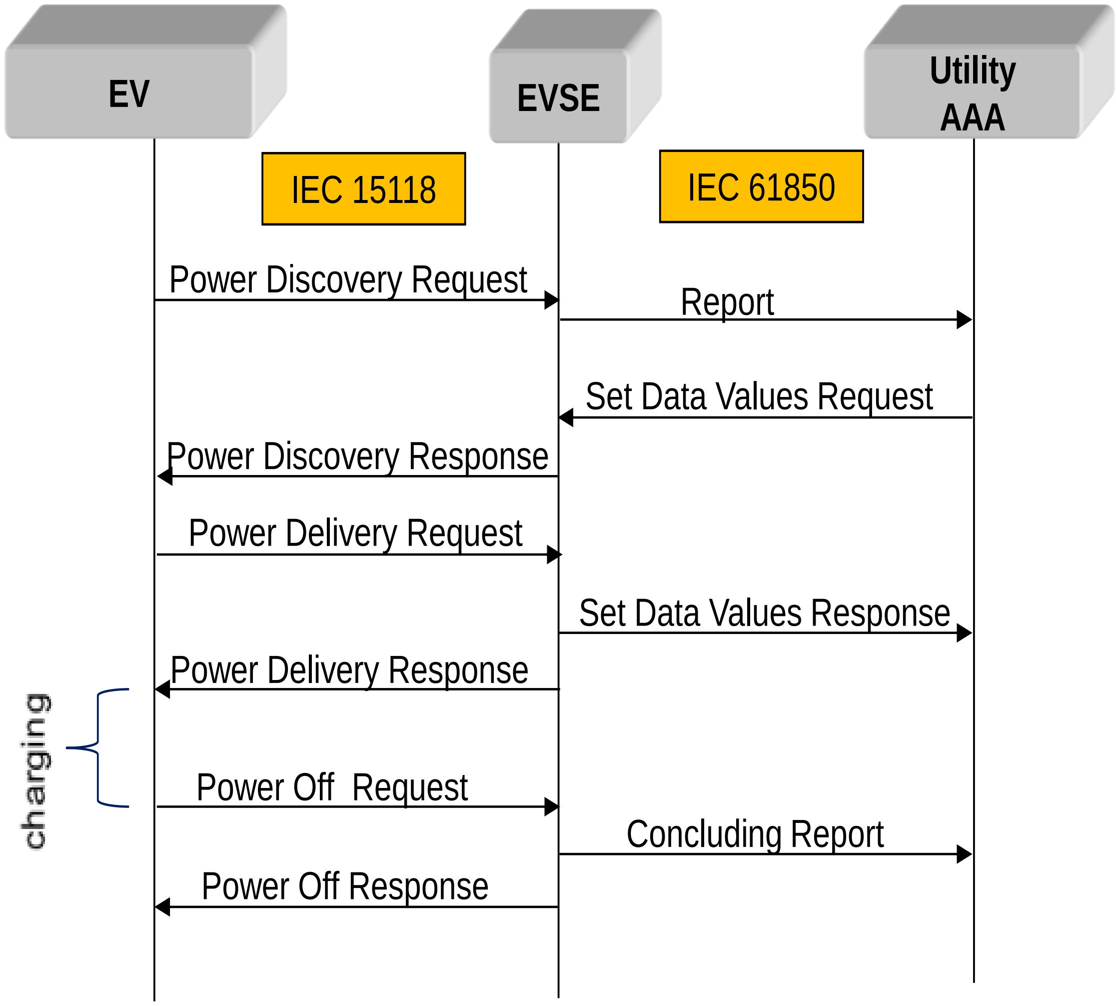

Figure 12 Mapping between front-end and back-end messages

Although the ISO/IEC 61850 protocols is built for the standard substation communication, the factors for choosing it for V2G communications are Interoperability [22] – The ability of one or several manufacturers to exchange information and use the information for the own functions, the standard contains an object-oriented data model that groups all data according to the common user functions in objects called Logical Nodes and the data model and services of the standard are mapped to a mainstream communication stack consisting of TCP/IP and Ethernet with priority tagging[22].

Proposed Modifications in IEC15118 and IEC61850 protocols

To embody priority battery charging service for the AEEV, the ISO/IEC 15118 protocol (in figure 3) needs the addition of new messages between the AEEV and the EVSE. The new messages pertain to Priority Request/Response and Priority Levels. These messages must be executed before the establishment of battery charging session. Before power discovery step, the AEEV sends its EVID. EVID normally contain VIN (Vehicle Identification Number, a unique number assigned by the vehicle manufacturer to each vehicle), and the authentication credentials (defined by the utility operator for each EV/AEEV). In the current proposal, EVID is proposed to be modified so that Modified-EVID includes priority bit level (1-5) in addition to VIN and authentication credentials. Priority would be given according to the priority level assigned to the AEEV. Priority levels would be assigned and provisioned by the government agency. These parameters will be easily programmed into the AEEV/EV.

Similarly, the IEC 61580 protocol also needs the addition of new messages between EVSE and Utility AAA to support priority treatment. The proposed modifications in the protocols are shown in Figure 13 and are explained in the following paragraphs.

When the EVSE receives the priority session request from the AEEV which is contained in the EVID, the EVSE routes the request to the Utility network. Rest is same as explained in section 4.1.1 for Priority Charging Service invocation from home utility network or visiting utility network.

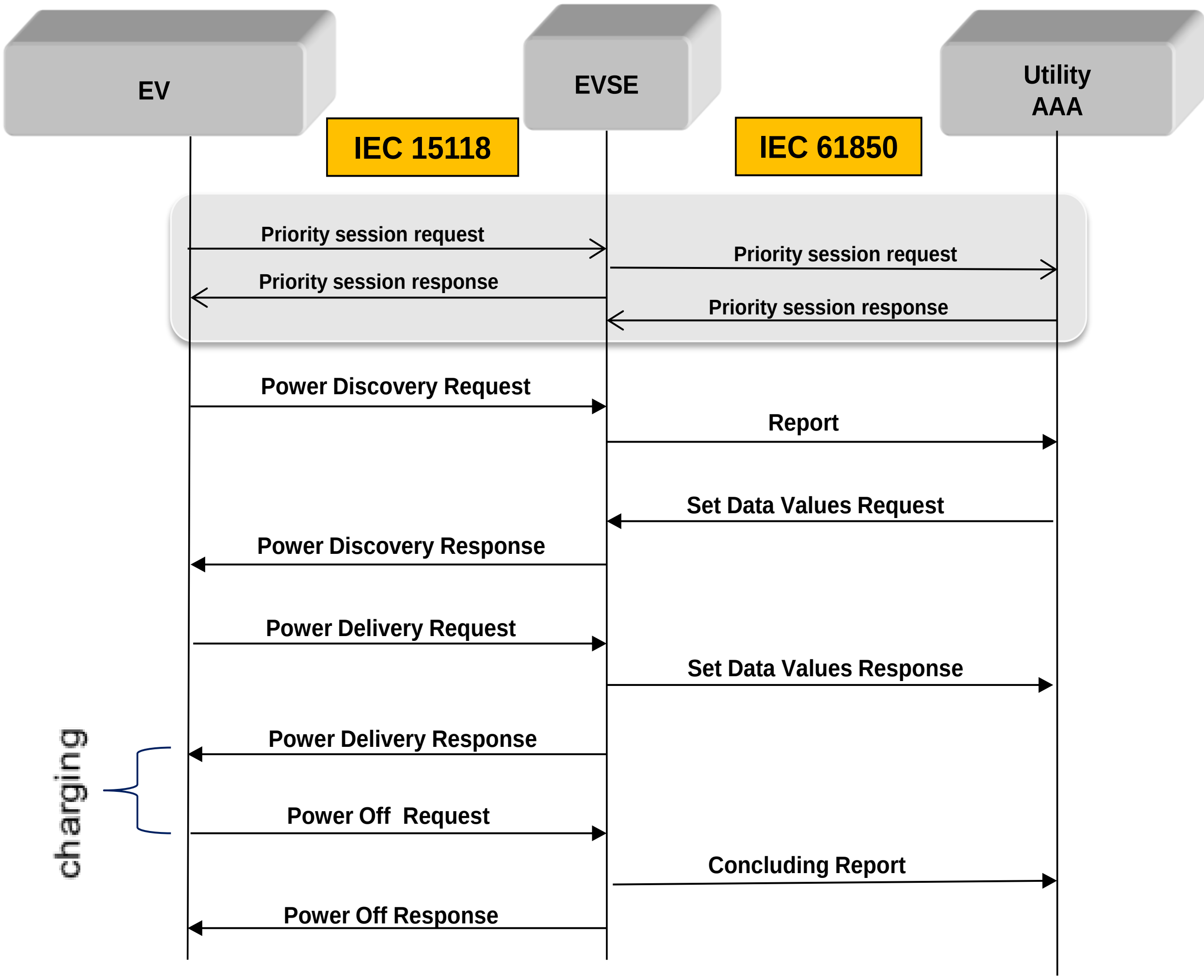

Figure 13 Modification of IEC15118 and IEC61850 protocols for priority treatment

Home Network Scenario

When the AEEV is in its home network, the EVSE will send priority service request to the utility network through the Serving Router (SR). The request is first authorized/authenticated by the home AAA, then by the PCS. PCS database contains registered EVIDs of the AEEVs and their corresponding priority levels. After validation of the request at home AAA, and the PCS, the Policy Server (PS) of the serving network will apply network's policies. (After AAA/PCS authentication/authorization, acknowledgement will be sent back to the EVSE corresponding to the line lock signal.

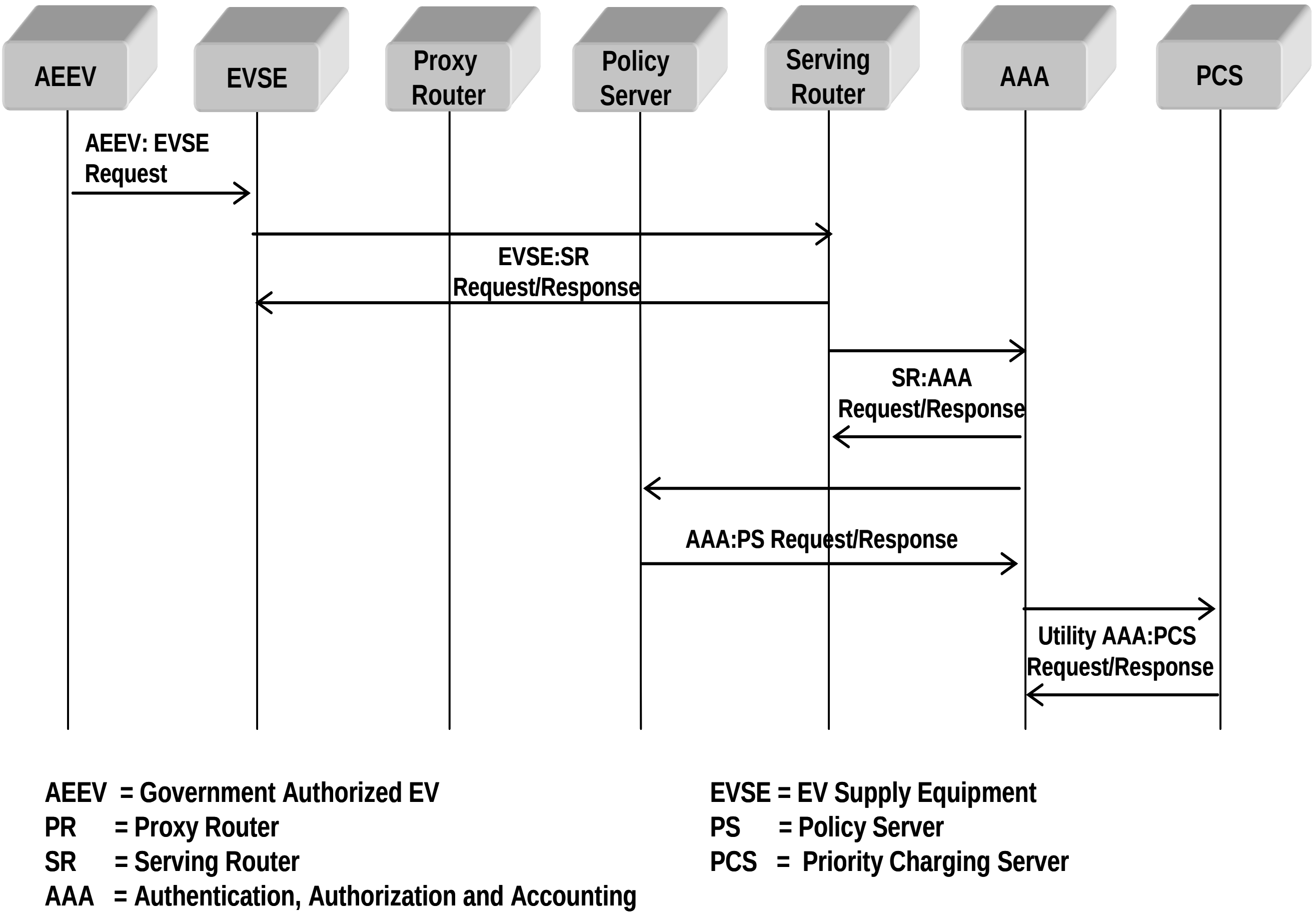

Figure 14 Charging from the home network scenario

Roaming Scenario

When the AEEV is roaming, it would initiate the charging request through the EVSE of the visited network. Its service request would be routed through the proxy server of the serving network. The rest is same as mentioned earlier. (I.e. AAA, Policy server (PS) and PCS of the home network will be contacted for validation). After validation of the request, the EVSE of the visited network will provide the service.

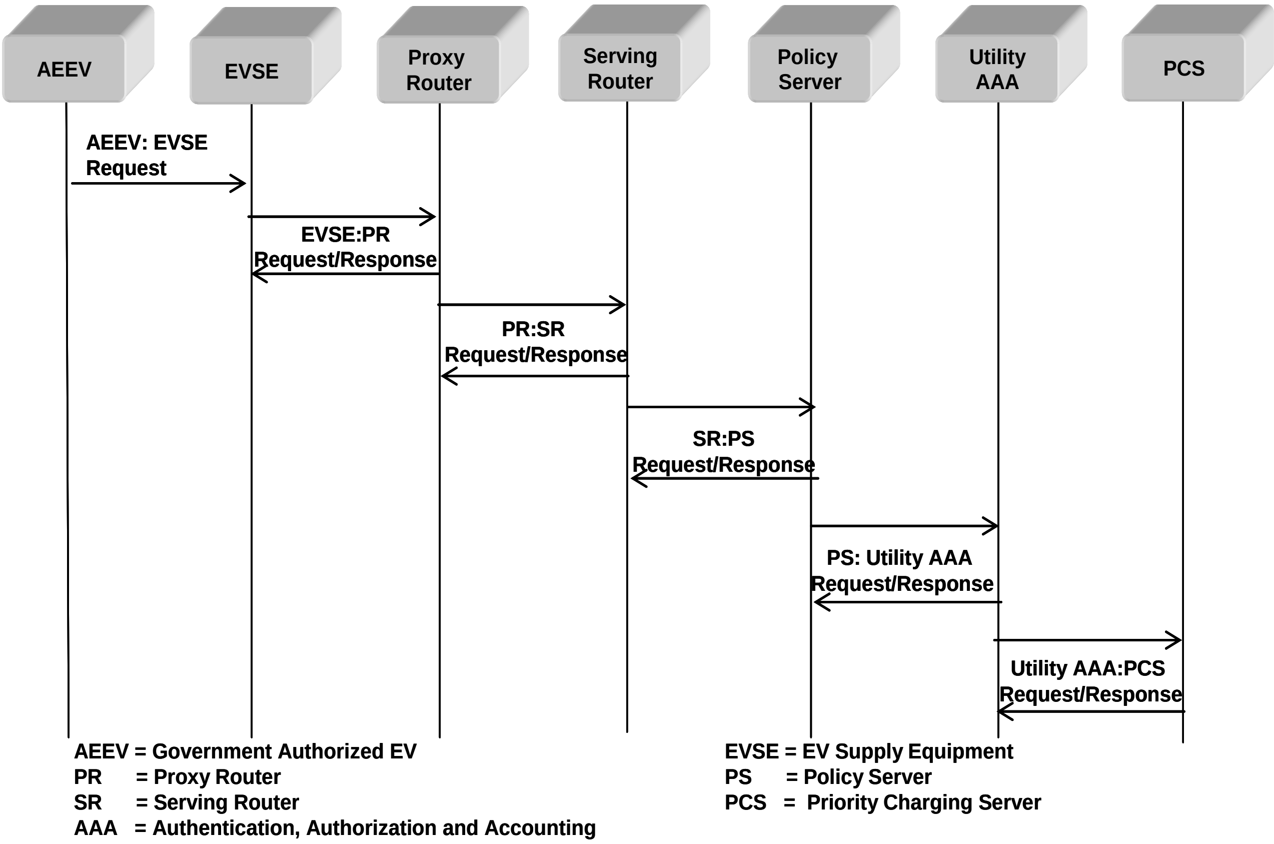

Figure 15 Charging from a visited network (Roaming) scenario

One of the benefits of having multiple priority levels is the fact that AEEVs can have dynamic priority treatment according to different criteria. For example, an AEEV can have priority one in week days and priority 5 during the weekends. Further depending on the level of the government officer, or nature of emergency dealt by the AEEV, the corresponding priority may be assigned.

Sub priority-levels can be added as a business model for billing purposes, for example a regular user can have the choice to charge with a priority for a higher cost. In this case, he will be treated with priority level 6.1 which is higher than level 6.2 and so on.

In the OSI model, priority treatment should take place in the session layer as shown in the following figure 16:

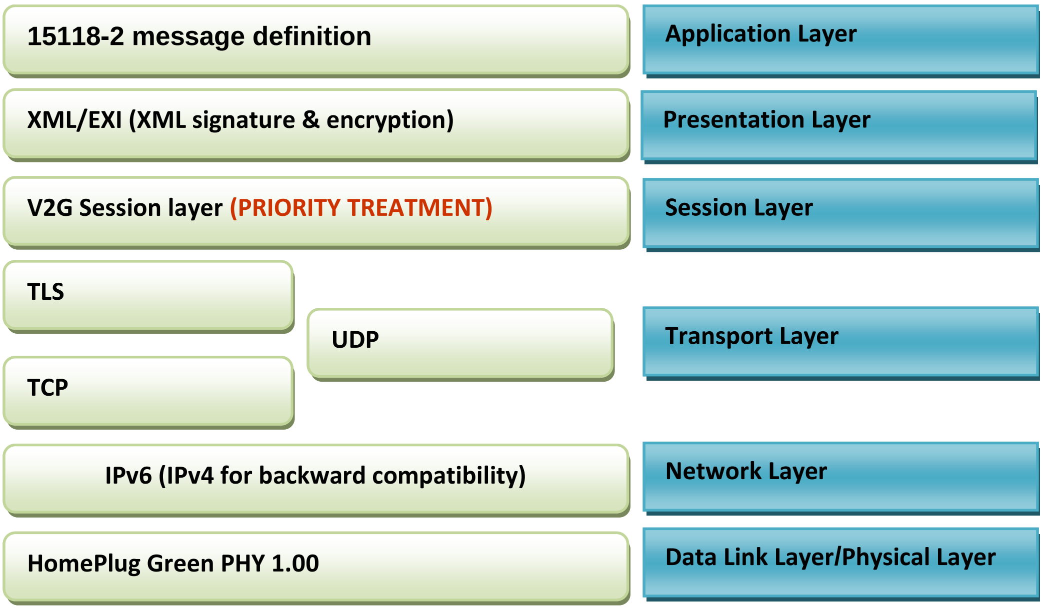

Figure 16 Priority Treatment in the TCP/IP protocol stack

CHAPTER V

EV PRIORITY: DESIGN TESTING AND SIMULATION

In this chapter, a simulation model for the priority charging is designed and functional flow chart for the simulation is explained. Lab VIEW virtual instrument testing software is used for designing and testing the priority charging internal operations. All the network operations involved in priority charging system are examined with using the simulation output results. Other Application platforms that can be used in implementing the EV priority charging are discussed.

Simulation Model Design Specifications

The main objective of this simulation is to execute switching commands to control the controller switch residing at EVSE from the database. The controller switch device allows electrical power to the EV by following the command signals received from grid operations database. The input variables like EV ID, port number, IP address and priority levels are transmitted to the database for process resulting in response command to the EVSE, Controller switch. The Grid operations database comprising of AAA, policy server, priority charging server and power monitoring database, these entities are responsible for declaring the power switching and scheduling commands. The grid operations database is integrated with the power load analysis system, to check the strains on the power grid that may cause potential damage to the systems involved in power distribution.

When an EV is plugged in to the EVSE, the communication unit, SECC invokes TCP/IP connection for sending a request to power distributer's servers, the acknowledgement from the database confirms the establishment of secure connection. By default port number and IP address of the requested client will be enrolled in the database. After the connection is established, EVSE (through SECC) will forward the unique EV hardware id (VIN number) to the grid controller database for the authentication process; subsequently on successful authentication the priority identification process starts, which involves the priority debug function carried out in priority charging server(PCS). Once the priority of EV is identified, the database corresponds with the power grid load analyzer for verifying the grid capability and load constrains, this process helps the database to determine whether to provide immediate charging or a scheduled charging.

When multiple EV charging requests are received by the database at a same instance of time, the database uses the priority sorting algorithm for sorting the highest priority devices from the list and starts executing the power enable commands in a queue fashion. During the peak load time, the charging for high priority device will be scheduled, and the lower priority level EV charging will be preempted.

The EVSE comprising of controller switching device acts vital backbone for the backend processes, it executes the power supply switching commands received from the database. The command based switching will be the final function of EVSE in the process of activating power supply. The database commands received through TCP/IP connection are decoded and fetched by SECC and later on an operation specified commands are forwarded to the controller switch. Bifurcating complete objectives of simulation into two processes, the functions of each process is explained in step by step procedure.

Network side processing/ backend processing

- Connect EV to the network
- Network registers EVID
- Network obtains the locational information using IP address and port number

- Network Authenticates EVID
- Network Determines EV Priority
- Network Authorizes EV priority
- Network checks the power availability
- Network Schedules the charging

EVSE processing

- Establish connection with network. (network discovery)
- Send a connection request to database (query for grid controller database)
- After database accepts the connection, it sends EVID, port number, IP address and other hardware related specification.
- Execute commands received from database.

Flow chart representation of simulation

The control flow starts from the EV is plug in event. IEC 15118 and IEC 61850 protocols create the communication benchmark between EV and grid control database for the charging session. EVSE sends a connection request to the grid database. As the TCP/IP connection by default, obtains source address information at the time of communication initialization, no special functions needed to identify the source IP addresses and port numbers. After establishing a connection with the database, the EVSE sends EV identification information to the database to perform authentication. In this operation, Authentication server debugging takes place for identifying whether the EVID received from the EVSE is registered in the database or not. If the EVID case match is found in the database, Authentication server will be forwarded EVID and authentication success signal to priority server for performing priority look up operation; else the authentication failure string will be replied to the EVSE. The priority lookup function uses the priority database tables, which comprises of detailed catalog of the EVID's and their respective priorities.

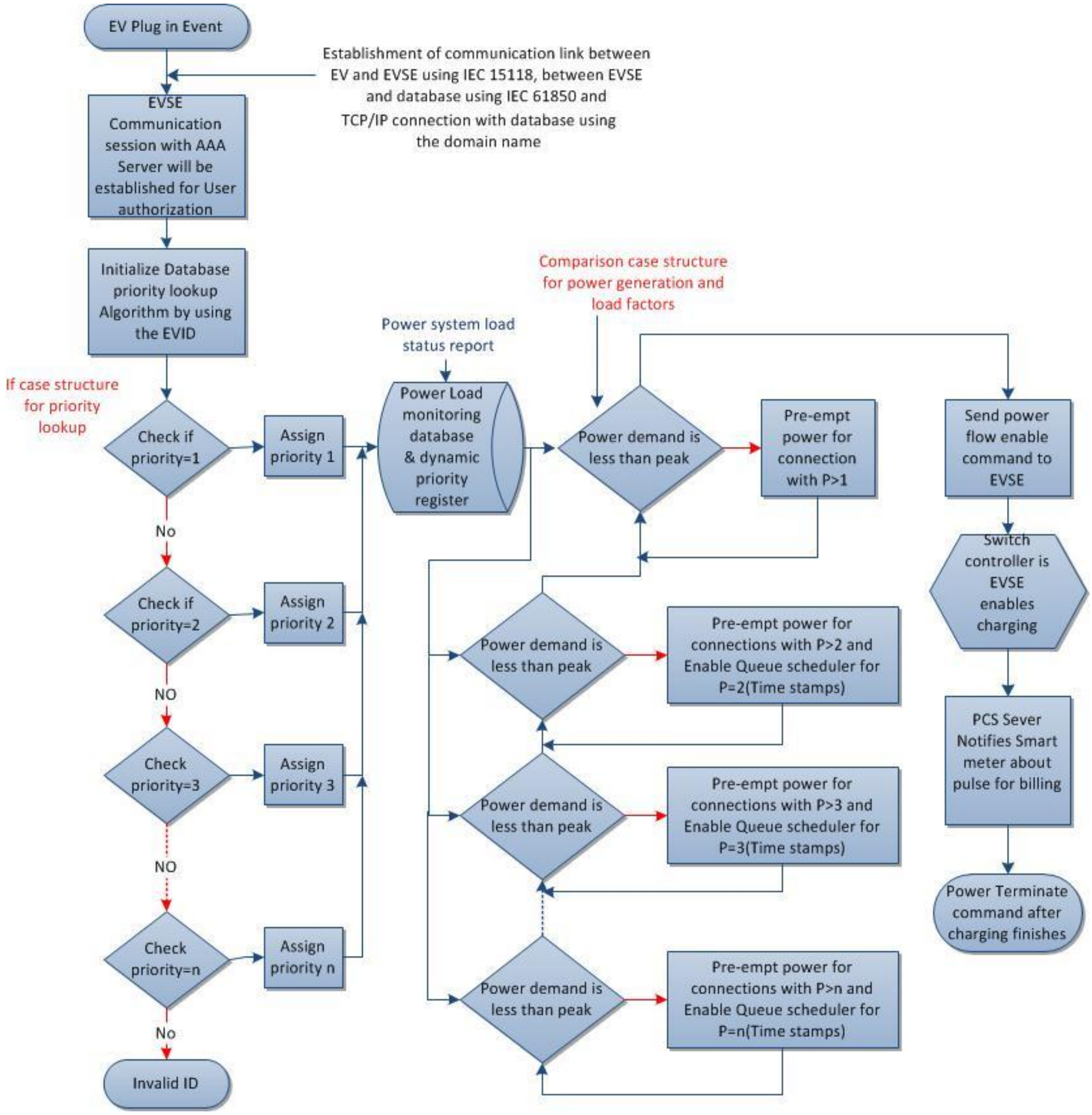

Figure 17 Flow Chart representation of EV priority simulation model design

The priority look up operation output values will be in decimal format; these outputs are sent to the power load monitoring database for checking the load status of substations at a specified location from where the charging request was made. The power load database has the critical load information of the power grid which is collected from the PMU (phasor measurement units) deployed all over the grid.

The power load database decides whether to provide the charging to the EV or not, depending on the grid load parameters. If the load on the gird is at its peak and a new charging request is received, then the database performs reflexive operations to preempt the power connection for low priority EVs and also purge it's EVID from dynamic charging list. When all the other connected EV's are of the same priority, the database schedules the charging for the later period and indicates the charging schedule to EVSE by using the special commands.

Lab VIEW

Lab VIEW is virtual instrument simulation software, used in building and verifying the feasibility of the real time devices for obtaining desired or implicational outputs. It supports both digital and analog models. It can also be used for enhancing the efficiency and effectiveness of the hardware design [23].

The graphical block diagram codes are used for building the hardware model from the theoretical idea. The preprogrammed block tools available in the lab VIEW can be directly used, or the attributes of the available tools are manipulated for getting the expected output. These block diagrams that are built using lab VIEW are called virtual instruments [23]. The Lab VIEW also supports the data acquisition by interfacing with external hardware devices.

In this simulation for priority charging, the lab VIEW virtual instruments are designed for performing the Authentication of EVID, priority lookup, EV scheduling and TCP/IP communication between the database and EVSE. These virtual instrument in comprises of structured loop functions, string variable, data converters, XML file decoders, TCP/IP initialization tools and TCP/IP listener tools.

EVID Authentication and Priority look up VI

The Authentication is a backend network process. When the EVID is received from the client in a binary format; these values are compared with the stored database EVIDs. If the EVID matches with the database value then authentication will be successful. The priority look up is a function performed after authentication is a network process, it uses both the EVIDs and priority database tables to identifying the priority, i.e. it performs priority authorization using priority lookup tables in database. In theoretical concept, when the SECC sends the user data to the AAA server, the authentication of the EVID is carried out and later data will be forwarded to priority server. Similarly, in this simulation the results will be either the 'authentication success' by which the EVID data will be forwarded to priority lookup function or it replies with the 'user ID not found' string where the user is indicated with negative integer (-1) at EVSE display unit. After the EVID had been authenticated, the priority VI executes the priority lookup function for identifying the priority of the EVID. The priority server database file will be xml format separated by comma is used for storing the EVID and priority, which is shown in the following table 2.

Table 2 Table emphasizing database stored values (EVID and priority)

EV_ID	PRIORITY
67:UA:N8:09	1
89:H0:Sk:O1	3
B5:22:GG:I3	4
EG:P8:J2:66	2
O7:EH:73:N4	5
8E:F2:PL:33	6
12:DF:HE:02	2

In priority lookup VI, the database file path is prefixed during the algorithm design for calling the stored values, so that the priority look up function uses the database files to compare the values and obtain the priority of specific EVID, from which the charging request had been received. The database maintains and updates with the list of registered EVID's and their priorities. As EVID is an input parameter for priority lookup function, whenever a data is received from output of authentication operation, priority lookup function considers the data as a numerically valid EVID listed in the priority database.

In the simulation, the priority comparison loops are active until the match case is found or until the end of database values. Once the EVID match is found the function outputs the priority of the requested EVID. The results for the priority lookup virtual instrument using the table 2 as database on lab VIEW simulation model is shown in figure 18.

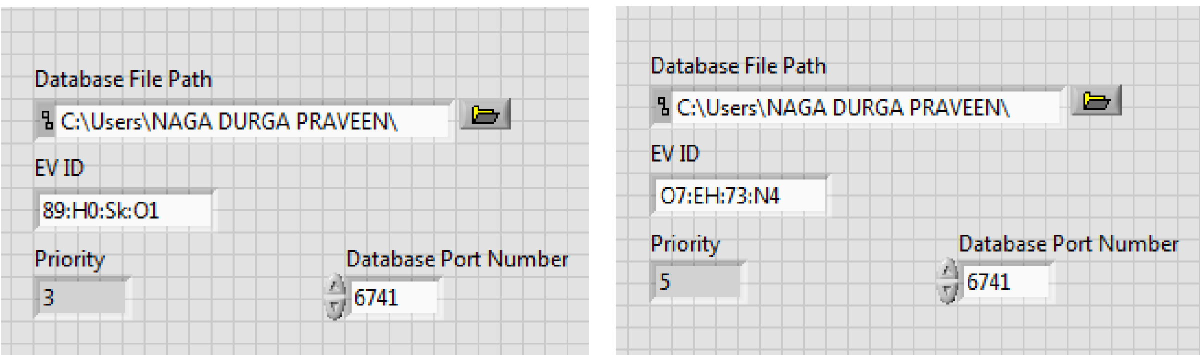

Figure 18 Database lookup simulation results for identifying the priorities by using EVID

Once the priority of the device is identified, the values will be used for sorting the high priority EVSE, for providing the immediate charging. These priority values are also used by the database for pre-empting the charging of other EV's with lower priority at the time of peak load.

Case for EVID authentication failure

When the EVID debug returns with null case, it is a condition for unregistered EVID request. In this case, the response of the database function will be a negative integer. Whenever a negative integer is received by EVSE from the database, it notifies the user with the string "EVID authentication is unsuccessful" or "-1". The simulation result for EVID authentication failure case shown in figure 19.

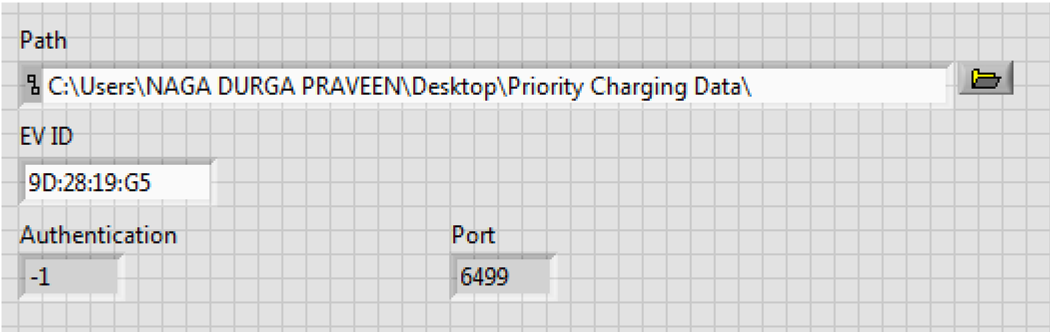

Figure 19 EVID authentication failure

Schedule Manager

In this design, it is assumed that the power grid is at the peak of its load. The scheduler function will be executed in the database after determining the priority of the EVID. The function of the schedule manager is to schedule the charging for the EV's in a queuing order based upon the timestamps created in the database at the time, when the request was made by EVSE. The Schedule manager rearranges the scheduling list in an ascending order by calculating the average of time at which connection request was made and priority, this formula enhances the schemes of priority scheduling, avoiding the unethical insertions of EVID in the schedule list. The port numbers in the schedule manger are useful to avoid conflict in the dispersion of command from the database (port number will give the accurate destination information apart from IP address).

The schedule manager is functionally divided into two components, the EV scheduler and the EV purge.

EV Scheduler

The inputs for EV scheduler are EVID, Port number and priority, when the scheduler receives the EV data from the database it records the time stamps and bundles it with the priority. The queuing list in the schedule refreshes automatically whenever it gets the new entry. Scheduler list will be sorted in ascending order of the average value for timestamps and priority. For the fair distribution of energy resources even to the lower priority devices, the time stamps are considered in sorting the schedule list.

EV Purge

This VI is used to eliminate the EVIDs from the charging list upon completion of charging. As discussed in chapter 2, the EVSE updates the battery charging level status reports to the grid database for Every 200 milliseconds, These status reports are examined by the database, and when the database receives the information that level of the battery charge reached its maximum, it sends a power connection terminate (controller switch disable) command to EVSE. Simultaneously, the database purges the EVID from the charging list.

During the time of schedule, the EVID’s that are enabled for charging are recorded in the temporary list. After the completion of charging, the database eliminates the EVID form the temporary list and archives the power usage periods in the database for further billing purposes.

The output list, as of show in the simulation output figure 20.

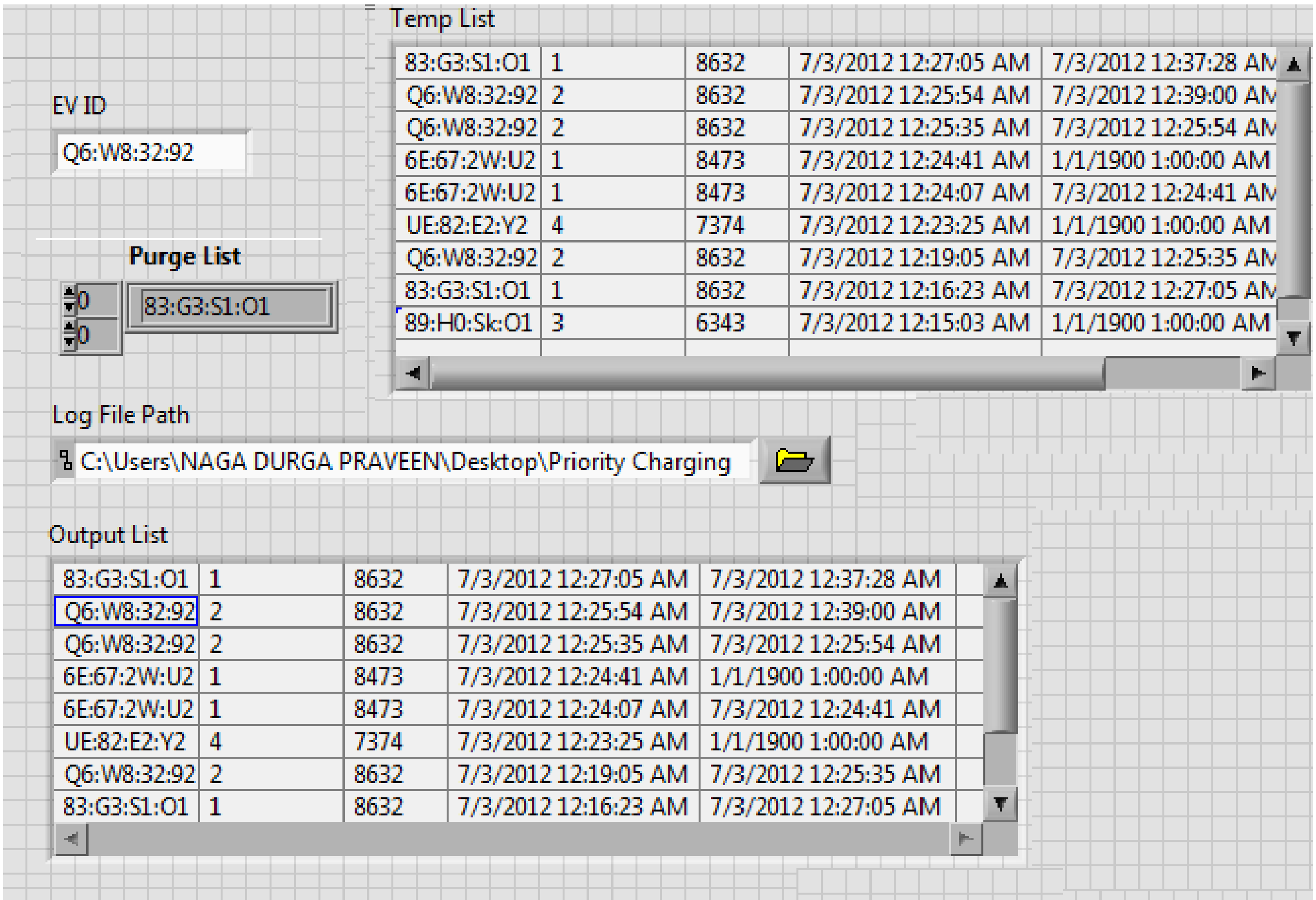

Figure 20 Results for EV purge; output list showing the power disconnected EVs

The schedule Manager is the integrated operation performed by EV scheduler and EV purge. The schedule manager gets the catalog of EV's that made a request for the power connection, these requests are arranged according to the priorities and time stamps, soon after the EV finishes charging it will remove the EV from the charging list and terminates the charging session. The simulated output for EV schedule manager is shown in the below figure 21 obtained from the simulation of EV scheduler VI in lab VIEW. Schedule manager also store a log file in the database for creating the billing and user reports.

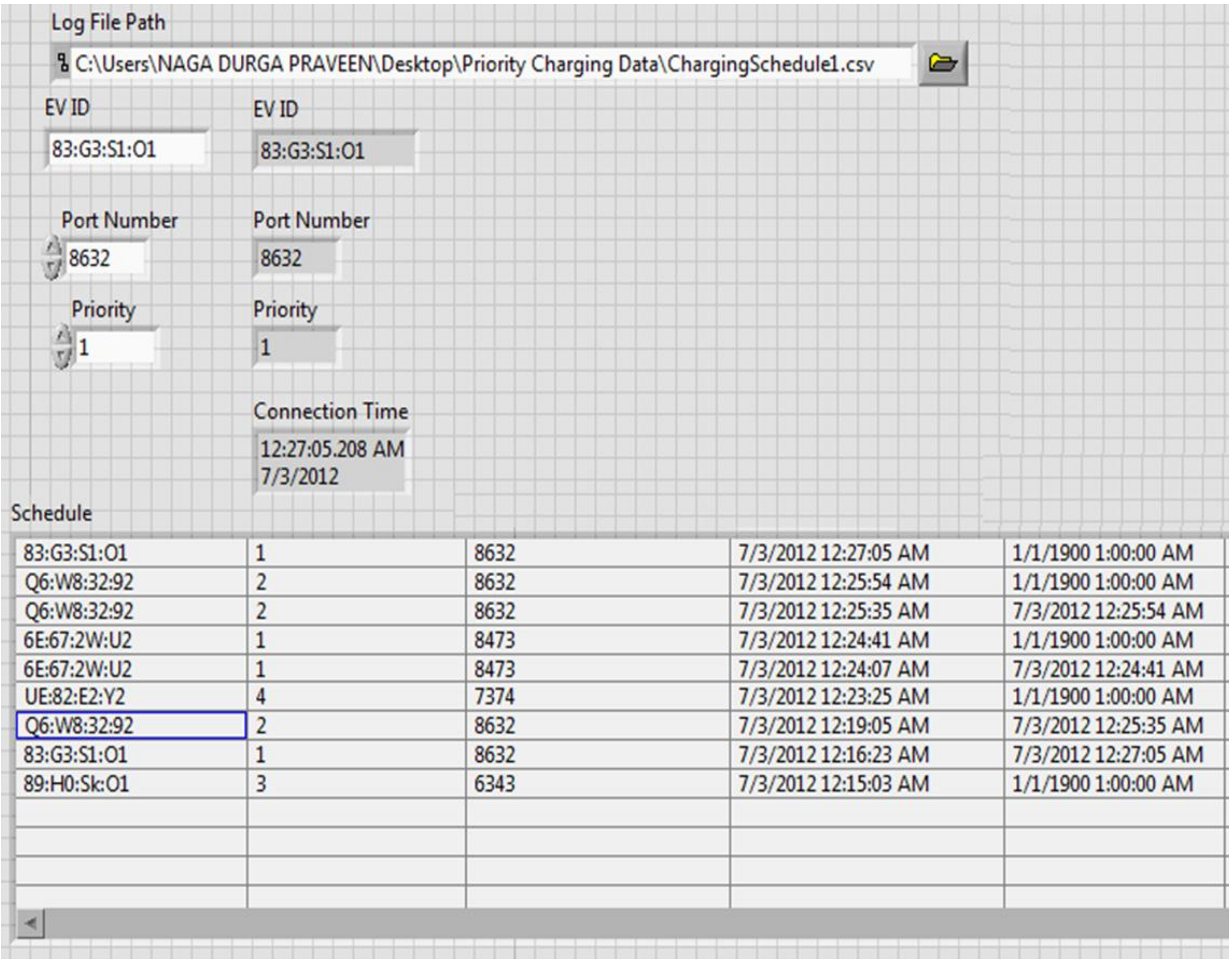

Figure 21 Screen shot for simulation output for EV Scheduler

TCP/IP Operations between Server (database) and Client (EVSE)

When the connection is established between the (Database) server and the client (EVSE), the server stores the IP address and the port number of the source and client in the memory buffers. Those details are used for building the dynamic algorithms, which enables the message exchange using IP addresses between source and destination in most efficient path.

In the simulation of TCP/IP server VI, the connection request from the client VI invokes the data exchange operations. The client VI has the unique port number and IP address which helps the server to identify the client's location. These IP addresses remains in the temporary memory registers of the server until the communication session ends. After the establishment of connection, the client forwards the user information to the server, which performs the authentication and priority identification processes. The server even performs the scheduling upon the requirement and sends the power switch control commands to the client (EVSE). The output showing the command received by the client for enabling the control switch in EVSE is "CSEN" and the command for disable the control switch is "CSSC". The simulation of TCP/IP connection using the server VI and client VI is obtained and the figures below shows the observed outputs at the client end, after successfully receives the commands of server. Apart from the commands a client- server status updates take place in the background of TCP/IP connection.

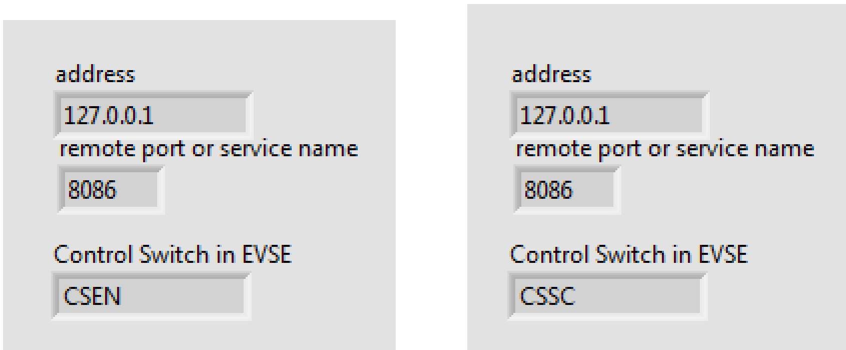

Figure 22 Commands received by Client (EVSE) to Enable and disable the control switch

Embedded Webserver Application for Priority Charging

All the functions of the VI that are discussed so far are compactable for embedding in the web server, the server applications are programmed using the same logical methods that were successfully implemented in the above simulations of Lab VIEW and database storage systems like MySQL can be directly used for maintaining the private records (EVID's priorities and user specific information). Similar to the theory, the web applications are capable to gather the port information and IP address with the EVID, before the setting up the charging session. The web server maintains the records for connection time and power dispatch time using which the computational operations are performed to calculate final bill for EV charging session.

The complete priority system management application can be built using the server application and secure gateways for transmitting the sensitive information among the server and the client can be merged in this application.

Conclusions and Results

The Virtual instruments involved in the communication process of priority charging are simulated for obtaining the power enable signal from the database. The components involved in priority charging, EV authentication and priority lookup, EV scheduler and TCP/IP connection are successfully integrated, for execution under the virtual testing environment. The application is successful in resolving the host database domain names and obtaining the IP address and port number of the client (EVSE) during the time of connection. After making all the virtual instruments as an embedded program in a server application, it simplified the design and improved the performance of all the operations that are required for priority scheduling and charging. The final output is obtained in the form of communication signal to EVSE to enable the switch control, to start charging for the highest priority devices and the lower priority EV's got the Schedule information, which can be seen on the server application output screenshot.

Simulation Design Discrepancies

Due to the Static buffer storage in the TCP/IP listener port the previous entry commands are not erased which is causing the redundancy in commands this faults can cause undesired activities on EVSE. These faults can be avoided by using the dynamic buffers in the real time system. (Note: real time TCP/IP systems have the dynamic buffers with variable buffer capacities).

The current system is not apt for preempting operation, as the integration of power grid monitoring system is needed to perform such operations. This requires multiple external hardware tools (Phasors etc.), as this simulation model is restrained to software model; the complete system is not demonstrated. In this simulation model, it is assumed that the power system is at its peak load. In the real time grid operations, as the phasor measurement units are already deployed among the grid, to collect valuable consumption data, it makes sense in the design of viable priority charging system.

CHAPTER VI

CONCLUSION

This thesis proposes an architecture for preferential charging treatment for government authorized emergency electrical vehicles. One of the major functional entities to realize such a service is a database server that registers and maintains the ID's of the authorized vehicles. Others include routers for routing messages to enable the authorized emergency vehicles to get the priority battery charging service. The architecture allows the service provisioning from any utility operator other than home utility operator. Yet some other functional entities are databases such as billing database, and policy, charging (billing), Scheduling and rules databases. These databases process accounting, authorization and billing information based on serving utility company's policy and charging rules. This thesis also suggests modifications in the IEC15118 and IEC 61850 protocol suit that enable communication between V2G (Vehicle to Grid).

Future Scope

Future work can be done to enhance the security features of the model to avoid the spoofing of the EVID and unauthorized priority usage. The model can be made capable of generating automated notifications to the user personal devices to update the user about the charging status and billing information. Improvements can be made to the architecture of the priority charging system in visitor network to reduce the processing time and to provide the immediate charging to the emergency vehicle at the remote locations.

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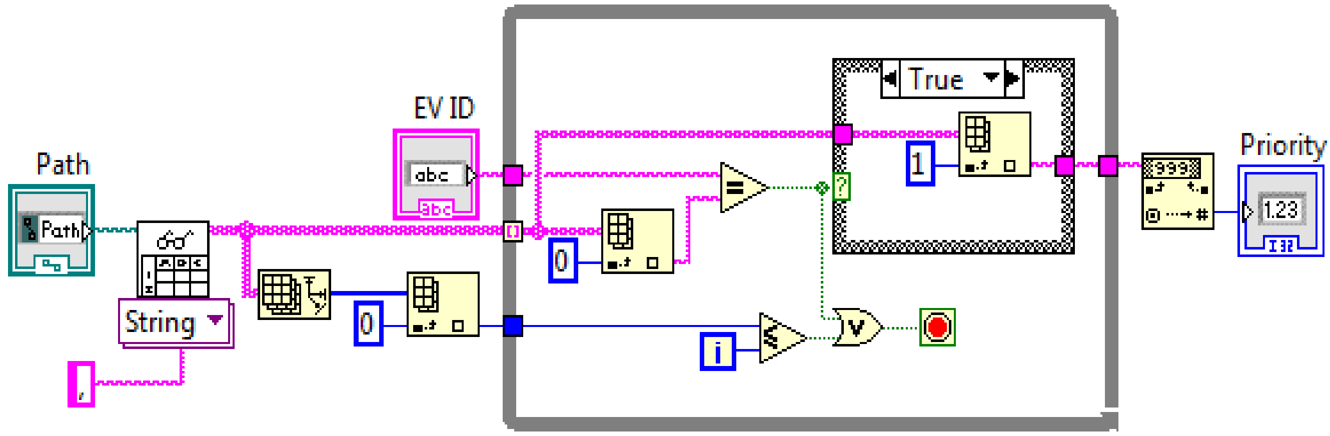
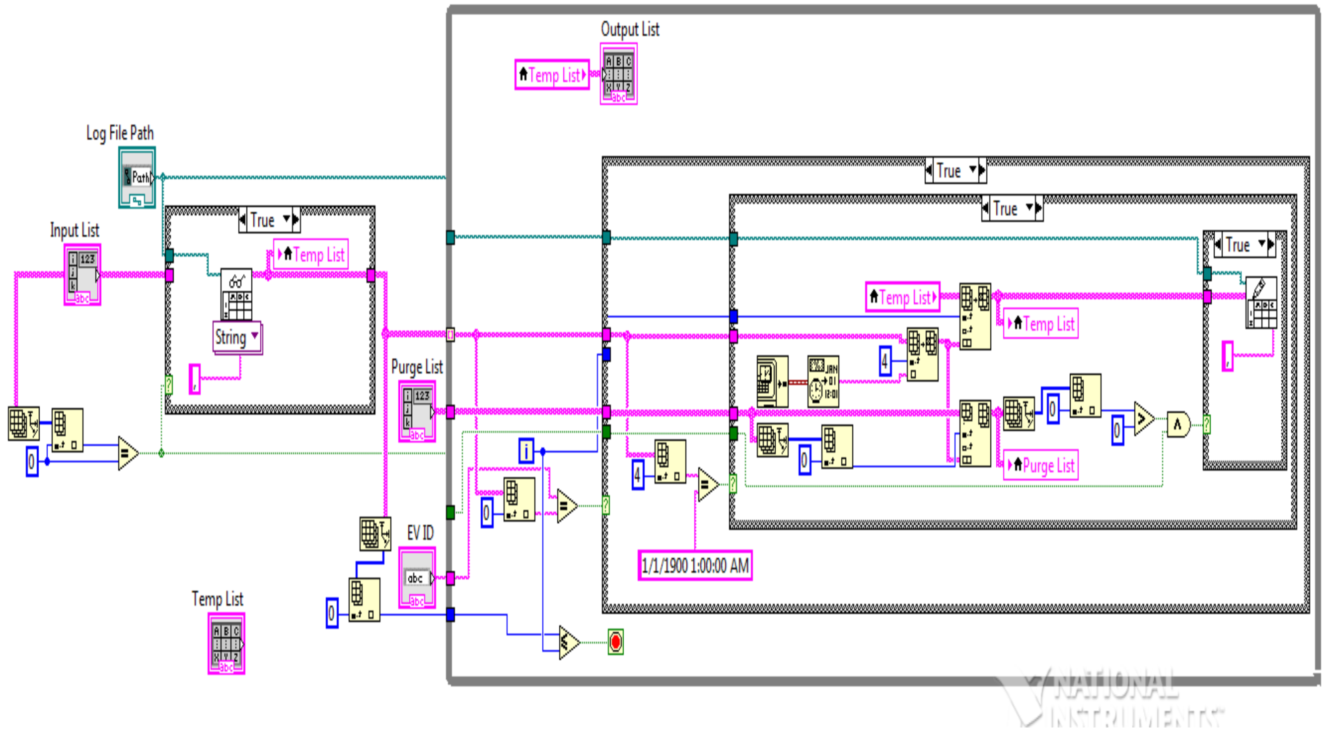
APPENDIX A

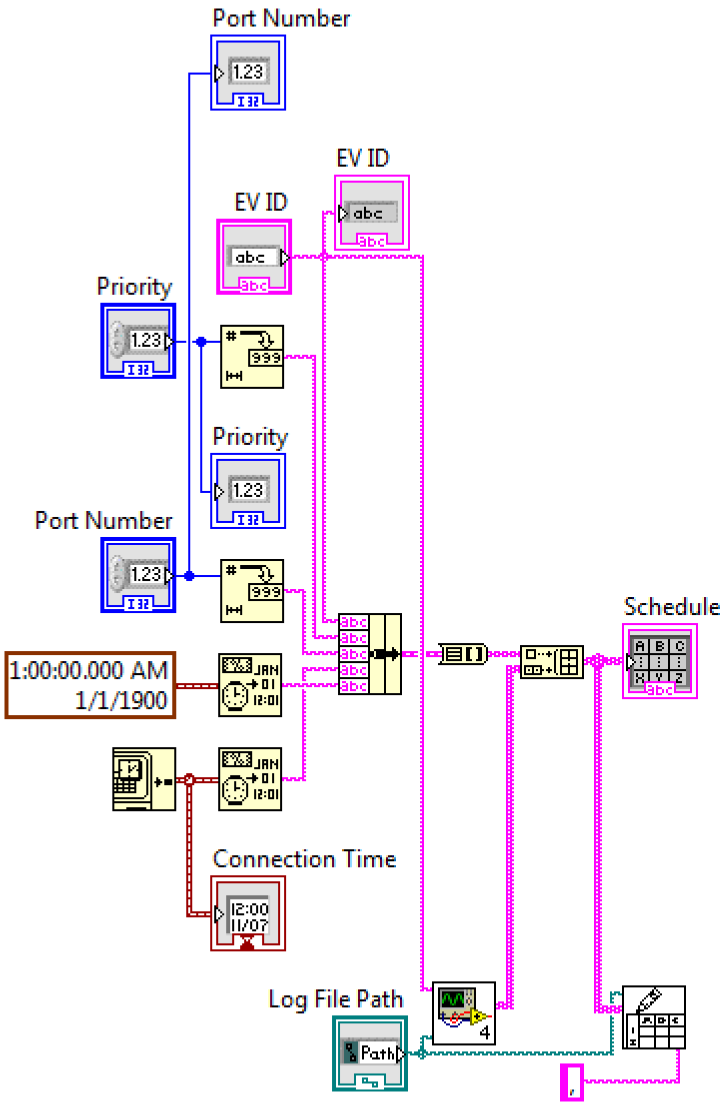
LAB VIEW VIRTUAL INTRUMENT COMPONENT DIAGRAMS



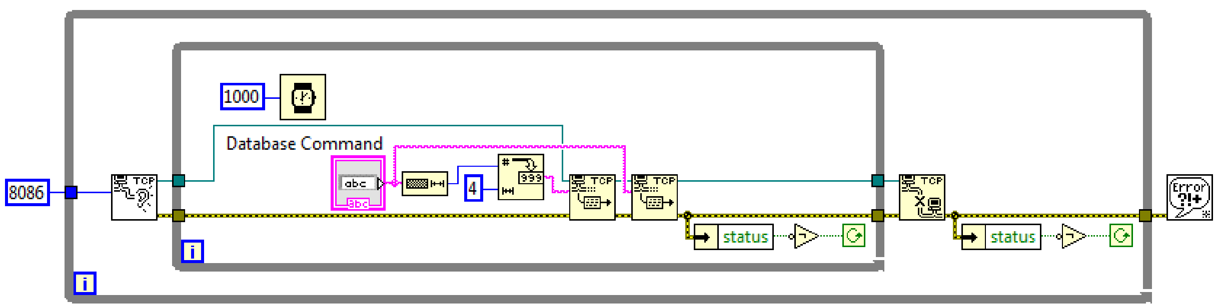
EV Authentication and Priority Lookup VI



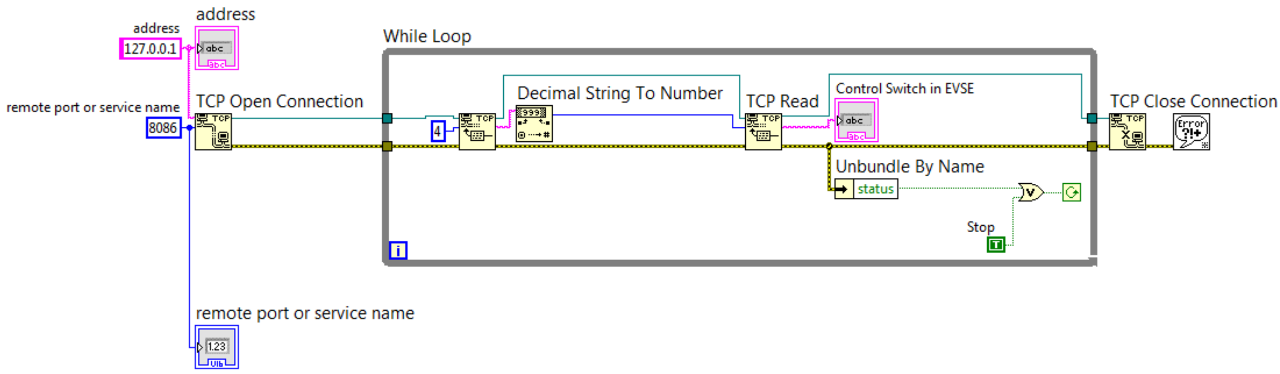
EV purge VI



Schedule manager VI



TCP/IP Server (Grid database)



TCP/IP client VI (EVSE)

VITA

Naga Durga Praveen Vemulapalli was born in Hyderabad, India. He completed his Bachelor of Technology degree in Electronics and Communication Engineering from Jawaharlal Nehru Technological University, Hyderabad, India. Naga started masters in electrical engineering in university of Tennessee at Chattanooga in spring 2011. Simultaneously, he worked as a graduate assistant for electrical engineering department up till May 2012. Naga graduated with a Master of science degree in Electrical Engineering (Specialization: Communication Systems) in August 2012.