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Partnership to Advance Clean Energy - Deployment (PACE-D) Technical Assistance Program

Detailed Project Report for MPUVNL: Centralized Monitoring Centre for Off-Grid Systems

January 2015

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PARTNERSHIP TO ADVANCE CLEAN ENERGY DEPLOYMENT (PACE-D)

Technical Assistance Program

Detailed Project Report for MPUVNL: Centralized Monitoring Centre for Off-Grid Systems

(January 2015)

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Acronyms

Acronym	Definition
AC	Alternate Current
CMC	Centralised Monitoring Centre
DC	Direct Current
DLMS	Device Language Message Specification
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HDMI	High Definition Multimedia Interface
IaaS	Infrastructure-as-a-service
ICT	Information and Communication Technology
IT	Information Technology
IP	Internet Protocol
JNNSM	Jawaharlal Nehru National Solar Mission
kWp	Kilowatt-peak
LAN	Local Area Network
Mbps	Megabits Per Second
MNRE	Ministry of New and Renewable Energy
MPSDC	Madhya Pradesh State Data Centre
MPUVNL	Madhya Pradesh Urja Vikas Nigam Limited
OEM	Original Equipment Manufacturer
OSF	Open Source Foundation
PaaS	Platform-as-a-service
PACE-D	Partnership to Advance Clean Energy - Deployment
PC	Personal Computer
SaaS	Software-as-a-service
SOA	Service Oriented Architecture
SPV	Solar Photovoltaic
TA	Technical Assistance
TCP	Transmission Control Protocol
USB	Universal Serial Bus
WAN	Wide Area Network
XML	Extensible Mark-up Language

EXECUTIVE SUMMARY

With the introduction of Jawaharlal Nehru National Solar Mission (JNNSM), the central government and several state governments have developed, through their policies and programs, an enabling and conducive framework for harnessing solar energy resources in India. The private and public sector entities too have initiated programs for the addition of solar energy-based power generation systems and applications.

Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL), as the state nodal agency for the state of Madhya Pradesh, under the guidance of Ministry of New and Renewable Energy (MNRE), undertakes implementation of various solar energy programs in the state. MPUVNL is actively implementing off-grid Solar Photovoltaic (SPV) programs in Madhya Pradesh, under which several off-grid SPV systems have been installed across the state. As the program is subsidy-driven, MPUVNL sees the need to monitor the performance of the systems. Currently, there are no commercial linkages between the subsidy disbursement by the central and state government and the performance of the off-grid SPV system. The establishment of a Centralised Monitoring Centre (CMC) system and data collected by it can be used to link the subsidy given to the off-grid systems with their performance.

- **<u>Need for development of CMC for MPUVNL</u>**

Currently there are123 off-grid SPV systems, installed by different off-grid vendors in the state. The installed capacity of each system varies from 1 kWp to 100 kWp. These are either standalone systems or hybrid systems with grid supply as a backup. As per the directives of MNRE, it is mandatory to install remote monitoring devices for off-grid SPV systems with installed capacity of more than 5 kWp. This feature is introduced to ensure effective monitoring of the system. It is expected that day-to-day online feedback from these systems would be received by MPUVNL headquarters. It was envisaged that using the remote monitoring facility, corrective actions would be initiated for improving the performance of the system. Unfortunately, due to the lack of adequate staff and their pre-occupation with other aspects of the programs, the remote monitoring facility has not taken off as expected. To achieve the monitoring objectives, a CMC is sought to be established at the headquarters of MPUVNL at Bhopal.

The CMC will collect generation data from all the off-grid SPV systems located in various parts of the state and MPUVNL will access this data through an online user interface. The monitoring will help in understanding the functioning of the off-grid SPV systems and help improve performance, reduce down-time and gain confidence of user institutions.

MPUVNL has entered into a Memorandum of Understanding (MOU) with USAID India for availing technical assistance in the arena of renewable energy through the PACE-D TA

Program. MPUVNL has particularly sought assistance from the PACE-D TA Program in the following activities towards establishment of the CMC:

- Feasibility evaluation of project
- Preparation of Detailed Project Report (DPR)
- Support in tendering process to find a CMC systems developer
- Assistance in development and implementation

- **CMC: Selection of model for development of CMC**

The PACE-D TA Program has conducted a preliminary feasibility study of the project and explored two different models to establish the CMC.

Model 1: Off-grid facility-level meter integrated with centralized monitoring system
In this option, the system will collect data from the meters installed in each off-grid system. The existing meter and data logger in off-grid systems of different vendors are not Device Language Message Specification (DLMS)-compatible; hence the communication of these meters with third-party devices/systems is not possible. A new set of metering and data logger arrangement with DLMS compatibility will be installed at each off-grid system. This data logger will collect data from the meter through RS 232 /RS 485 ports, depending on the meter compatibility, and transfer the same to the database of the CMC system through GPRS mode of communication. The GPRS services will be availed from any of the state's leading mobile network service providers. Once the data is received by the CMC database, it can be analyzed and stored in the database for presenting to users through an interactive web-based online interface.

Model 2: Off-grid vendor-based centralized monitoring system
Here, the system will use the existing remote monitoring facility installed by the off-grid vendors. The remote monitoring system consists of a data logger at each off-grid installation, mobile network for communication and a server to store the data. The data logger collects the data and transfers the same to the server through the GPRS/GSM-based communication network. The server to collect and store the data for off-grid installations is owned or rented by the off-grid vendor. In this method, there are around six to eight different servers (depending on the number of off-grid vendors) that collect data from the off-grid installations. These servers will export the data in a uniform format and interval to the CMC system database. The data will be analyzed and stored by the CMC system for presenting to the user through an interactive web-based online user interface.

Based on an evaluation of the two options, and the views of MPUVNL, it is recommended to establish the CMC through an off-grid vendor-based centralized monitoring system. In the upcoming chapter, all the references, cost estimation, project specifications, etc., will relate to Option 2, i.e., **off-grid vendor-based centralized monitoring system**.

While in the present scenario, MPUVNL has considered establishment of the CMC through Option 2, for the future programs, Option 1, i.e., off-grid facility-level meter integrated centralized monitoring system, may also be considered by other state agencies. In that case, while designing the program, it is recommended to include the necessary provisions and specifications of the CMC system, remote meters and data loggers in the program document, so that the implementation of Option 1 will be easier.

- **CMC: Salient features and important functionalities**

The main design features of the CMC system include modalities of access to the generation data, status of individual off-grid installation, frequency of data transmission, granularity of data interval, and protocol for updating and verifying the generation data of each off-grid system. Besides, design features include presentation of data in a user-friendly format (graphical/excel table) through a web-based user interface, options to classify the data based on off-grid vendor/district/type, display features for the user interface at MPUVNL, alarms, trends and report generation in the web-based user interface.

While designing the CMC system, the following assumptions have been made in design consideration:

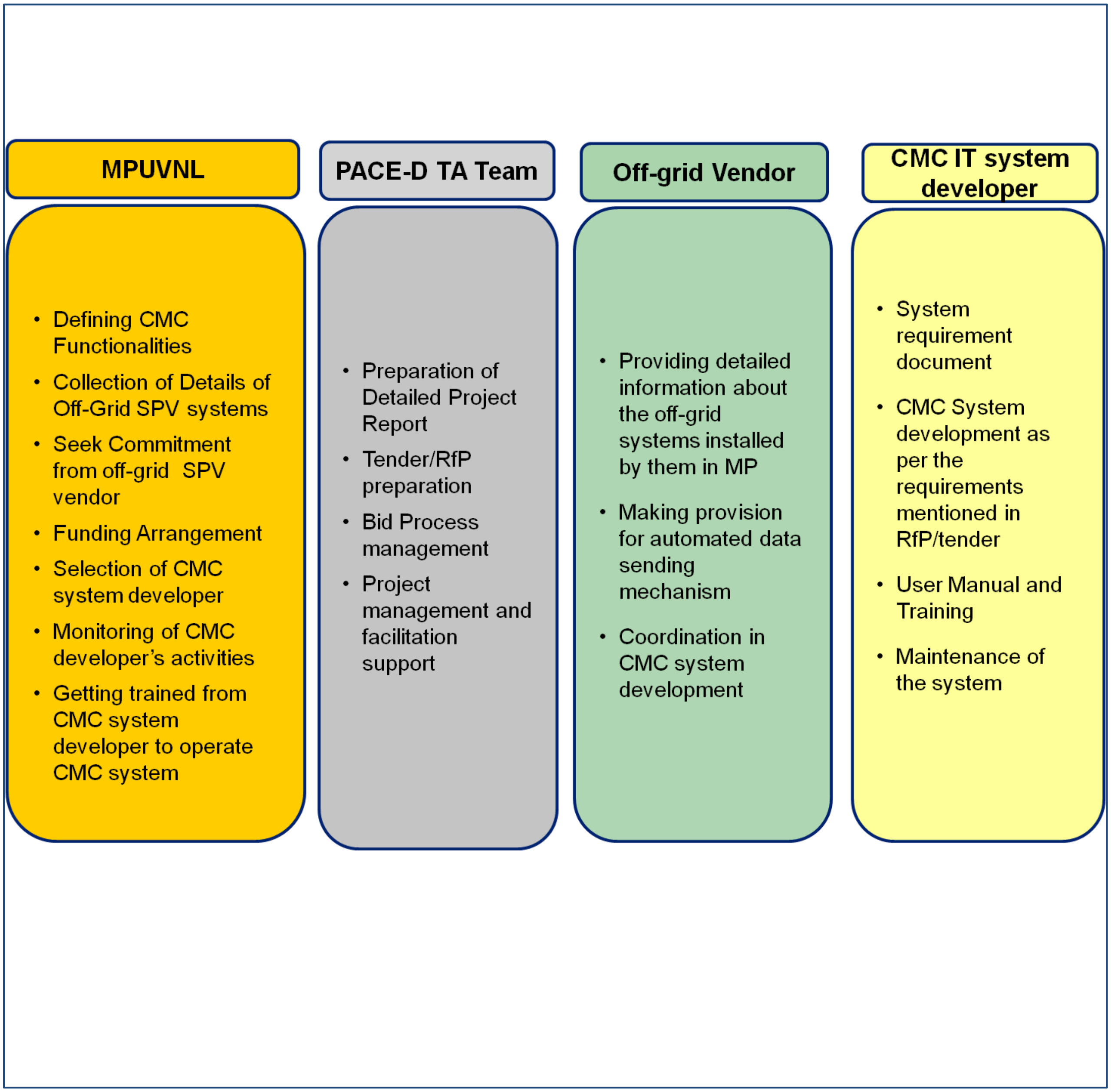
1. The CMC system will monitor DC Voltage, DC Current, kWh reading of the DC meter, and AC meter reading of grid supply AC Voltage, and Current and AC meter reading of consumption load wherever applicable.
2. The off-grid vendor system will send the generation data report on an hourly basis[*] and the granularity of generation data will be to the extent of 15/30/60 minutes (as feasible).
3. The user interface will have provisions for the different types of users - MPUVNL, off-grid vendor, and general public to access the CMC system with separate login and access control features. The user will have access to a web-based online interface that has the functions of alarm, automated mail services on reports, etc.
4. No manual intervention should be involved in data collection and data analysis. The data transfer mechanism between the off-grid vendor's server and the CMC system should be fully automated, using any of the advanced secure file transfer protocol.

- **CMC development: Roles and responsibilities of key stakeholders**

The main stakeholders involved in the development of the CMC system are MPUVNL, PACE-D TA Program, CMC IT system developer and off-grid vendor. The roles and responsibilities of these stakeholders are represented in Figure-1.

[*] Time to be finalized before tender specification for selecting CMC IT system developer

Figure-1- Roles and Responsibilities of Different Stakeholders



- **<u>CMC: Budgetary cost estimate (development and operating)</u>**

Based on the design considerations and functionalities of the CMC, the budgetary cost has been estimated for its development at around **INR 46.17 lakh plus applicable taxes**. This amount includes the costs for hardware, infrastructure, software and implementation. The development of the CMC system will be awarded to the CMC IT system developer on turnkey basis.

In addition, there are certain recurring costs involved for server applications, license fees (if any), communication and bandwidth, and annual maintenance contract charges for the IT system operator. To operate and maintain the CMC system, MPUVNL will need to budget for an estimated **INR 8.17 lakh/annum, taxes extra**. No manpower cost has been budgeted under this head, as it is assumed that existing manpower with MPUVNL will be adequate to monitor the CMC system during the operating phase.

- **CMC: Roadmap for development**

To ensure reliable and fail-safe operations of the CMC system over the long term and to develop mutual confidence amongst the organizations involved, it is recommended to award the CMC system development and maintenance project to the selected CMC IT system developer for a period of at least three years. Hence, during the selection of the CMC IT system developer, the terms and conditions will be specified to include system development on turnkey basis and maintenance of the system for three years.

There are four stages involved in the development of the CMC - Conceptualization, Pre-Development, Development and finally Post-Development. The complete cycle of CMC system development, which starts from the feasibility study to the *go live* stage of CMC system operation, will take approximately 11 months.

- **CMC development: Way forward and role model for other states**

The purpose of the CMC system is to help MPUVNL in monitoring the performance of the off-grid SPV system. In future, the same system can be used to monitor other off-grid system applications such as bio-gasifiers, solar-wind hybrid systems, solar pumps, etc. Currently, the subsidy disbursement is not linked to the performance of the off-grid SPV system. The establishment of the CMC can help MPUVNL link the subsidy given to the off-grid systems with their performance. The proposed off-grid CMC system is the first of its kind in India.

Upon successful implementation of the CMC system by MPUVNL, the same model or the off-grid facility-level meter integrated centralized monitoring system can be implemented by other state nodal agencies in the country to monitor off-grid systems.

For future upcoming programs, MNRE/state nodal agencies may consider including a similar kind of performance monitoring system and linking the subsidy disbursement with performance. This will enhance the utility of the program for the beneficiaries and help them in monitoring the program outcomes in an effective manner.

1 INTRODUCTION

1.1 BACKGROUND TO THE REPORT

With the introduction of Jawaharlal Nehru National Solar Mission (JNNSM), the central government and several state governments have initiated policies and programs for an enabling and conducive framework to harness solar energy resources in the country. The private and public sector entities too have initiated measures for the addition of solar energy-based power generation systems and applications. In recent years, the growth of grid-connected solar power systems has contributed significantly to the power generation capacity. The development of decentralized/off-grid solar power generation systems/applications have also played an important role in addressing energy access challenges and helped in deployment of clean energy solutions in remote areas.

Madhya Pradesh Urja Vikas Nigam Limited (MPUVNL), as the nodal agency for the state of Madhya Pradesh, under the guidance of Ministry of New and Renewable Energy (MNRE), undertakes implementation of various solar and renewable energy programs in the state. MPUVNL is guided by the State Government's policies and programs in this field as spelt out by the Department of New and Renewable Energy, Government of Madhya Pradesh.

MPUVNL is presently implementing off-grid Solar Photovoltaic (SPV) programs in Madhya Pradesh, under which several off-grid SPV systems have been installed across the state. As it is a subsidy-driven program, MPUVNL needs to monitor the performance of the off-grid systems. This can be achieved by establishing a Centralised Monitoring Centre (CMC) at the headquarters of MPUVNL.

It is necessary to have a clear definition and understanding of requirements and functionalities of the CMC system. This document titled "**Detailed Project Report - Centralised Monitoring Centre for Off-grid Systems - MPUVNL"** details the need for a CMC, its functionalities, components of system requirement, budgetary cost estimation, and roadmap to establish the CMC system.

1.2 OVERVIEW OF OFF-GRID SOLAR SYSTEM DEVELOPMENT IN MADHYA PRADESH

As a part of initiatives under JNNSM, MPUVNL is implementing several SPV programs in Madhya Pradesh. These programs are meant to promote and popularise the use of solar energy for reducing greenhouse gas emissions, combating climate change, saving of fossil fuels, conserving energy, and acting as an effective and reliable means of replacement of grid power, particularly in the remote areas.

Under the scheme, SPV power plants are developed with the aim of addressing the requirements of uninterrupted power supply for general use during the periods of power cuts. An

SPV power plant generates electricity from solar energy, stores it in a battery bank and supplies quality power as and when required, through a power conditioning unit. Many government and private institutions have utilized this scheme to install SPV power plants at their premises. The developers/users of SPV power plants benefit from subsidy provided by both the central and the state governments. The one-time subsidy is a portion of the capital cost of the project. The central and state governments together provide financial assistance in the range of 30 percent to 50 percent of the system cost (refer **Annexure I** for details on financial assistance provided to off-grid SPV systems in Madhya Pradesh). MPUVNL has selected various off-grid vendors for installation of off-grid systems in the state. The cost of procurement and installation of off-grid SPV systems has been standardized through competitive bidding among off-grid vendors. As of January 2014, 123 off-grid SPV systems have been installed across the state.

1.3 CENTRALISED MONITORING CENTRE (CMC)

As the SPV program has been initiated with government subsidy, it is necessary to have an effective system to monitor the performance of SPV systems installed. MNRE guidelines prescribe that SPV systems of more than 5 kilowatt-peak (kWp) capacity should be deployed with remote monitoring devices. The operationalization of remote monitoring systems has to be ensured for effective monitoring of the installed SPV systems and to explore improvements that can be incorporated in future program designs. MPUVNL is expected to receive day-to-day online data feedback from these systems and analyze the same to assess performance. (See **Annexure II** for the different user interfaces of remote monitoring systems related to SPV projects of different vendors). Because of lack of adequate staff and/or their pre-occupation with other routine tasks, the benefits of remote monitoring are not obtained to full potential. Currently, MPUVNL monitors the off-grid SPV systems through the remote monitoring setup (servers) installed by the off-grid vendor. While remote monitoring systems have been provided by the off-grid vendor, each vendor has provided a separate platform/web access/login feature, which necessitates MPUVNL to access each system separately for the purpose of monitoring and tracking. This is not only a time-consuming exercise for MPUVNL, but also limits the capability for orderly storage, compilation of data and comparative evaluation of performance of different SPV systems, and future analysis. Moreover, the number of off-grid SPV installations is expected to increase in future. Hence, MPUVNL wishes to set up a CMC at their head office (Bhopal), so that all existing and upcoming off-grid SPV installations in the state can be monitored effectively from a single location.

Currently, the purpose of the CMC system is to help MPUVNL in monitoring the performance of off-grid SPV systems. In future the same system can be used to monitor other off-grid system applications such as bio-gasifiers, solar-wind hybrid systems, solar pumps, etc. Currently, the subsidy disbursement is not linked to the performance of the off-grid SPV system. The establishment of CMC can help MPUVNL to link the subsidy given to the off-grid systems with their performance. The proposed off-grid CMC system is the first of its kind in India.

Upon successful implementation of the CMC system by MPUVNL, the same model or the off-grid facility-level meter integrated centralized monitoring system can be implemented by other state nodal agencies in the country to monitor their off-grid systems.

For future upcoming programs, MNRE/State nodal agencies may consider including a similar kind of performance monitoring system and linking the subsidy disbursement with the performance. This will enhance the utility of the program for the beneficiaries and help them in improving the monitoring of outcomes of the program in an effective manner.

1.4 STRUCTURE OF THE REPORT

This report has been organized under nine chapters:

i. **Chapter 1: Introduction –** This chapter offers an overview of MPUVNL and its roles and responsibilities in the development of off-grid renewable energy systems in the state, and details the present status of off-grid SPV systems in MP and the remote monitoring setup.

ii. **Chapter 2: Off-grid SPV Development in Madhya Pradesh and Need for CMC –** This chapter covers the details of current off-grid installations, and their types and functionalities. MPUVNL's existing practice of monitoring the current off-grid SPV systems and the limitations thereof are discussed. Key considerations and the justification for setting up an off-grid CMC by MPUVNL are spelt out.

iii. **Chapter 3: Models for CMC Implementation and Comparative Evaluation** – Two distinct approaches and solutions are identified for the establishment of the CMC. Each solution has its own merits and demerits. These solutions are discussed in detail in terms of scope of the solution, inputs requirement, flexibility and scalability, cost considerations, etc. An appropriate, viable solution has been selected for the establishment of CMC in MPUVNL.

iv. **Chapter 4: User Requirement and Functionalities for CMC –** This chapter spells out the details of MPUVNL's requirements - parameters to be collected from each off-grid system, the standard format templates for data collection from each off-grid vendor's server, etc. Derived from these requirements, the functionalities of CMC and model architecture have been defined. The scope of work of the off-grid vendor and CMC IT system developer for establishment of the CMC is outlined.

v. **Chapter 5: System Requirements and Components for CMC** – Based on the user requirement and functionalities of CMC, the basic system requirements are defined, and include user interface, database, necessary hardware and software.

vi. **Chapter 6: Stakeholders - Roles and Responsibilities for CMC Implementation** – This chapter identifies the various stakeholders and their roles and responsibilities in the implementation of the CMC.

vii. **Chapter 7: Budgetary Cost Estimation for CMC –** The project cost has been aggregated from individual cost components for hardware, software, communication, infrastructure, and recurring operating requirements. The basis for estimation of various cost components has been elaborated. The main purpose of budgetary cost estimation is to seek approval for sanction of funds and initiate further steps towards implementation of CMC.

viii. **Chapter 8: Roadmap and Timeline for CMC Implementation** – This chapter discusses the CMC implementation. The different activities and phases involved in the CMC project implementation are outlined and the estimated timeframe for various milestones in project implementation is indicated.

ix. **Chapter 9: Conclusion** – This chapter summarizes the project proposal and charts the use of the CMC system to cover other applications. It highlights the replicability and scalability of the CMC system for adoption by other states across India.

2 OFF-GRID SPV DEVELOPMENT IN MADHYA PRADESH AND NEED FOR CMC

2.1 THE EXISTING SYSTEM AT A GLANCE

MPUVNL has selected various off-grid vendors through a competitive bidding process for standardization of cost of procurement and installation of off-grid SPV systems across the state. The off-grid SPV project implementation is awarded to the selected off-grid vendors on a turnkey basis. These vendors have installed off-grid SPV systems at different locations across the state. As of January 2014, there are 123 SPV systems installed. This number is expected to increase in future. Table 2-1 shows the status of off-grid SPV installations over the years in the state of Madhya Pradesh.

The installed capacity of each SPV off-grid system varies from 1 kWp to 100 kWp. To ensure successful operation and to enhance user confidence, the off-grid vendors have been given the additional responsibility of carrying out comprehensive maintenance of the system for five years.

The existing off-grid SPV installations can be classified into three different models, based on the type of grid connection:

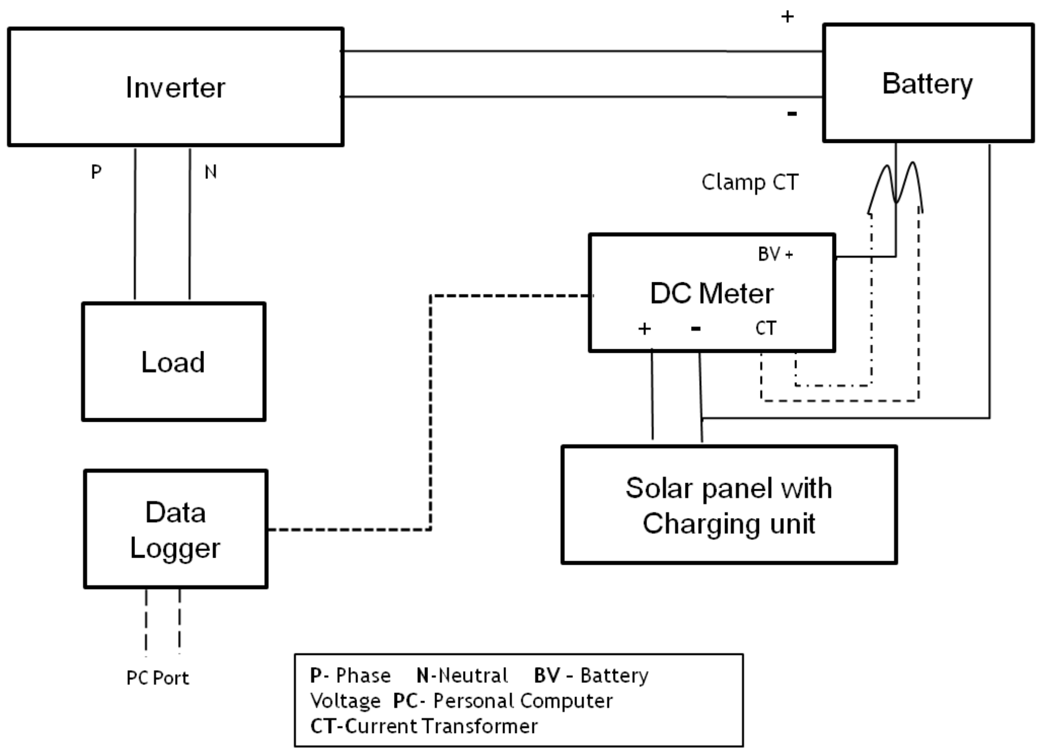
1. Stand-alone off-grid SPV system
2. Hybrid grid-tied SPV system – Single-phase grid power connection
3. Hybrid grid-tied SPV backup system – Three-phase grid power connection

Table 2-1: Status of Off-grid SPV Systems Installation in Madhya Pradesh, 2011-2014

Year	Number of Off-grid SPV Systems installed
2010-11	61
2011-12	36
2012-13	13
2013-14	13
Total	**123**
Work order placed in 2013-14	*120*

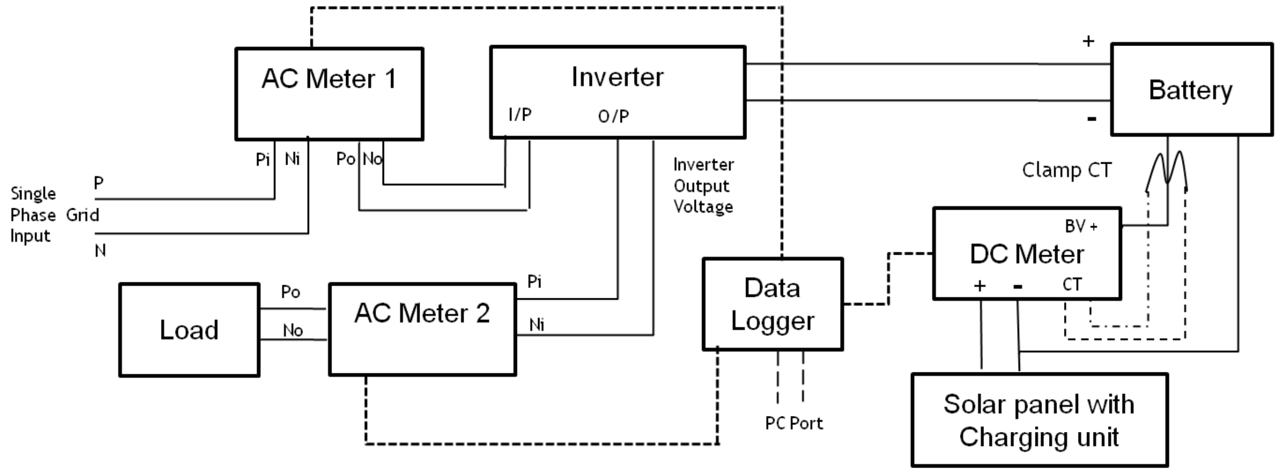
Stand-alone Off-grid SPV Systems: As the name suggests, this system is completely stand-alone, i.e., there is no backup support from grid power. The Direct Current (DC) power generated by the system gets stored in the battery bank and with the help of an inverter; the energy stored in the battery gets converted to Alternating Current (AC) and is supplied to the connected consumer loads. Figure 2-1 shows the single line diagram of a stand-alone system.

Figure 2-1: Standalone Off-Grid SPV System



Hybrid grid-tied SPV System - Single-Phase Grid Power Connection: This system includes an electricity backup supply from the grid. A single-phase AC grid power supply is connected to the inverter for charging the batteries in case power generated from the solar panel is not sufficient to charge the batteries fully. Figure 2-2 shows the single line diagram of a single-phase hybrid system.

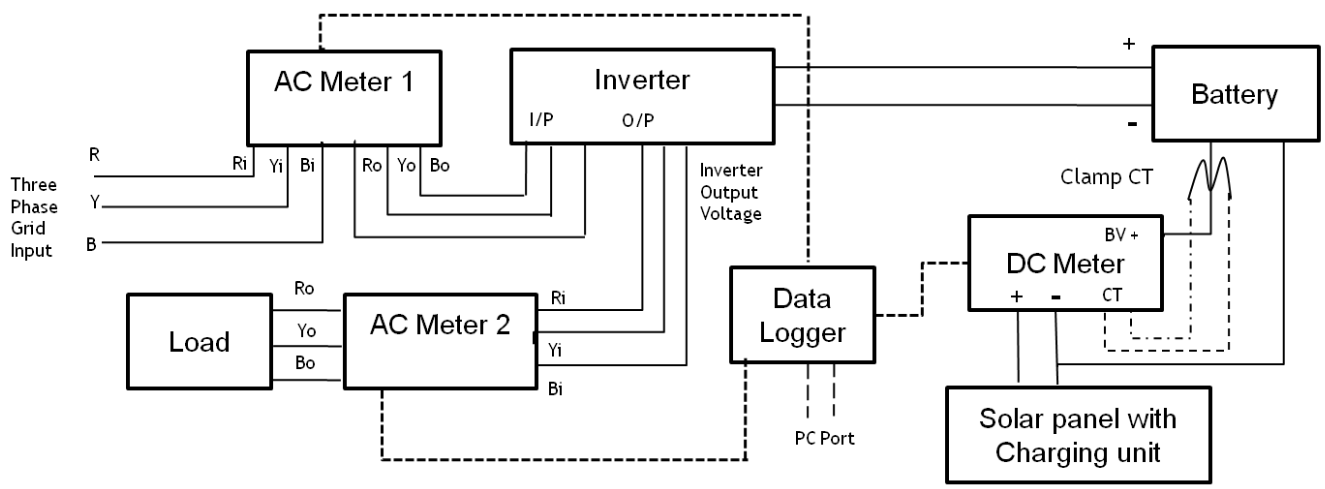
Figure 2-2: Hybrid System - Single-Phase AC Power Supply



Pi- Phase In Ni-Neutral In Po- Phase out No-Neutral out BV - Battery Voltage PC- Personal Computer CT-Current Transformer I/P- Input O/P-Output

Hybrid Grid-tied SPV System - Three-Phase Grid Power Connection: In this model, a three-phase AC grid power supply is connected to the inverter for charging the batteries in case power generated from the solar panel is not sufficient to charge the batteries fully. Figure 2-3 shows the single line diagram of a three-phase hybrid system.

Figure 2-3: Hybrid System - Three-Phase AC Power Supply



Ri- R Phase in | Yi- Y Phase in |Bi- B phase in | Ro- R phase out | Yo- Y phase out | Bo- B phase out BV - Battery Voltage PC- Personal Computer CT-Current Transformer I/P- Input O/P-Output

2.1.1 Remote Accessibility

MNRE's directives clearly require that the SPV systems with installed capacity of more than 5 kWp should be deployed with remote monitoring devices. This device will enable access to the generation data for effective monitoring of the system. Accordingly, the off-grid SPV system vendors have incorporated this remote monitoring facility for the off-grid SPV installations. The remote monitoring facility has a data logger that is connected to the meter through RS 232//RS 485 ports.

The data logger collects and records data on generation voltage, current in the SPV array, battery status, output voltage, load current and frequency, and units of electricity generated. The data logger can store data for about three months. The data can be either pushed or pulled towards the server depending on the communication mode. The data logger with GPRS modem pushes the data towards the server at regular interval. With a GSM modem, the data is pulled by the server at regular intervals. Each off-grid SPV system vendor uses his own server setup to collect data. This data is brought to the front end for user accessibility through an online web-based user interface.

2.2 NEED FOR CMC

The off-grid data logger is connected to the server maintained by the off-grid SPV system vendor. It transfers data to the server hosted by the off-grid system vendor at regular intervals. This data can be accessed through an online web-based user interface. As different off-grid system vendors have their own server setups and online user interface protocols, it is difficult for MPUVNL to monitor all the systems simultaneously. To access entire data for the state, MPUVNL has to access each off-grid SPV system separately. Currently, there are around eight to ten servers owned by different off-grid vendors. Considering the fact that the number of off-grid SPV installations will increase over time, it will be more difficult for MPUVNL to access the data from separate individual systems. Hence, a sophisticated automated and consolidated system is required to monitor all the off-grid SPV installations regardless of their ownership.

Accordingly, it is expected that the proposed CMC will overcome the above difficulties faced by MPUVNL in monitoring the off-grid SPV installations. The CMC is expected to consolidate the data from different individual systems, and analyze and provide automated and consolidated reports to MPUVNL.

In view of the technological advancements in the market today, the CMC can be established in multiple ways, using multiple approaches and models. Each technology has its own merits and demerits. Therefore, it is necessary to evaluate the different models available for CMC implementation.

3 MODELS FOR CMC IMPLEMENTATION AND COMPARATIVE EVALUATION

3.1 MODEL OPTIONS FOR IMPLEMENTATION OF CMC

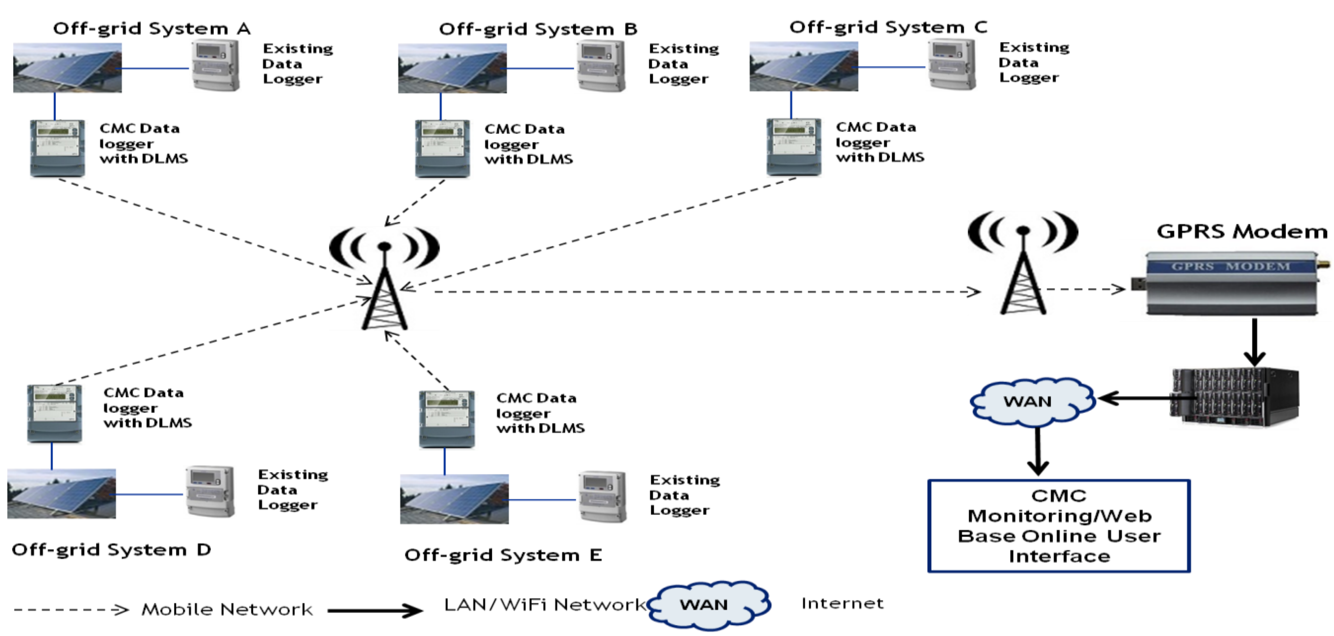
The CMC can be established through two distinct model options –

Option 1: Off-grid facility-level meter integrated system and ***Option 2:*** Off-grid vendor-based system. Both the models entail collection of data from all the off-grid installations and presenting it on a web-based user interface. However, the source of data, methods, and tools used for data collection will significantly differ for each model. Therefore, these models need to be analyzed on parameters such as complexity, time, cost, scalability, etc.

3.1.1 Option 1: Off-grid facility-level meter integrated centralized monitoring system

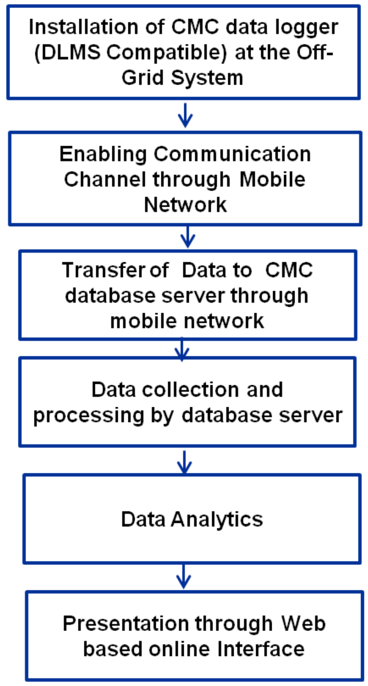
This system will collect data from the meters installed in each off-grid system. The existing meter and data logger in off-grid systems are not DLMS compatible; hence the communication of these meters with third-party devices/systems is not possible. A new set of metering and data logger arrangements with DLMS compatibility will be installed at each off-grid system. This data logger will collect data from the meter through RS 232 /RS 485 ports and transfer the same to the database of the CMC system through GPRS. The GPRS services can be availed from any of the state's leading mobile network service providers. The data received by the database is stored and analyzed for presenting to users through a web-based online interface. Figure 3-1 shows the model architecture for this system.

Figure 3-1: Model Architecture for Off-grid Facility-level Meter Integrated Centralized monitoring system



The process involved in this model is shown in Figure 3-2.

Figure 3-2: Process Flow - Off-grid Facility-level Meter Integrated Centralized Monitoring System



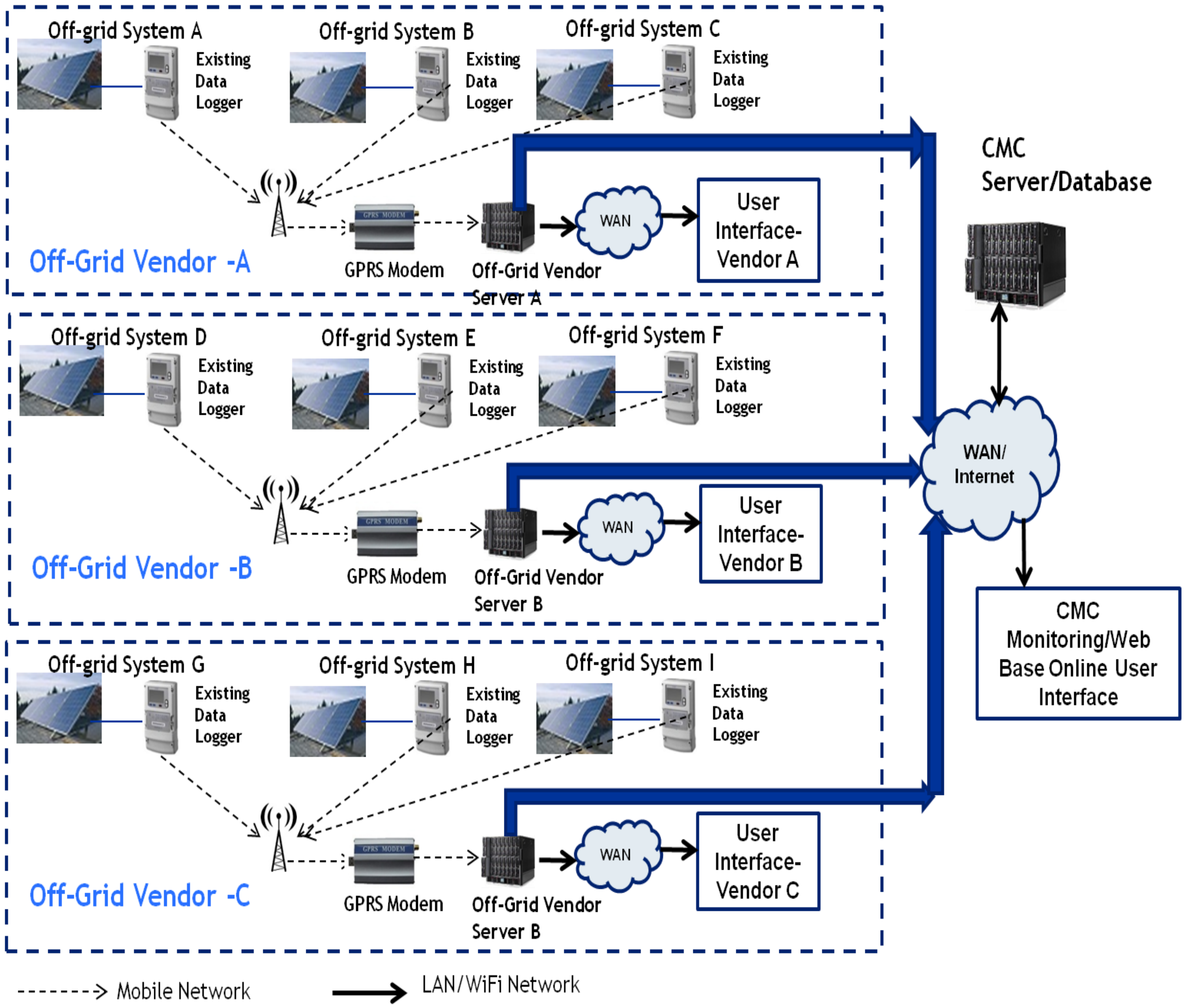
Merits: The main advantage of the system is that it uses a separate data logger to collect data from each off-grid system. Hence, this system is free from data tampering by the off-grid vendor.

Demerits: The installation of DLMS compatible meter, data logger and GPRS service will result in significant increase in capital cost and recurring expenses. Moreover, the maintenance of this hardware setup will be a complex exercise due to the geographic spread.

3.1.2 Option 2: Off-grid vendor-based centralized monitoring system

This system will use the existing remote monitoring system consisting of a data logger at each off-grid installation, mobile network for communication and a server to store the data. The data logger collects data and using GPRS/GSM, transfers the same to the server. The server is owned or rented by the off-grid vendor to collect and store the data for each off-grid installation. Thus, there are six to eight different servers (depending on the number of off-grid vendors), which collect data from the off-grid installations. These servers will export the data in a uniform format and interval. The CMC system database will receive the data, and analyze, store and present it to the user through an interactive web-based online user interface. Figure 3-3 shows the model architecture for this system.

Figure 3-3: Model Architecture of Off-grid Vendor-based centralized Monitoring System



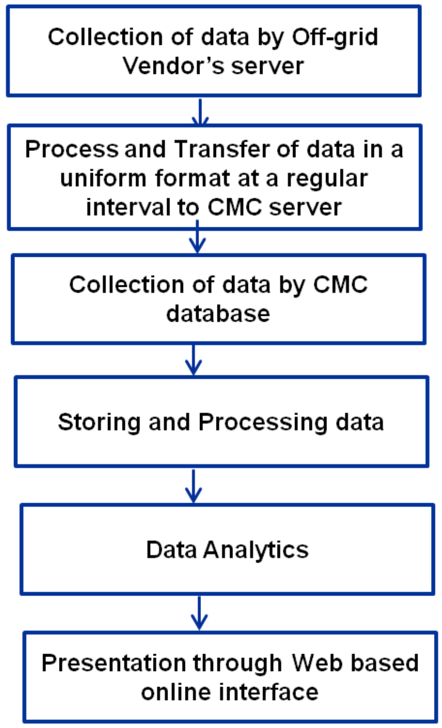
The process involved in this model is shown in Figure 3-4.

Merits:

1. As there is no need of a separate data logger to collect data from individual off-grid systems, the cost of implementation will be less.
2. The database and bandwidth are the only components that need to be scaled up for monitoring the off-grid systems; hence this system will be easier to scale up.
3. The hardware requirement is limited; can be easily implemented.
4. No mobile network services are required; reduces recurring cost. .

Demerits: The system collects data from the off-grid vendor's server. There is possibility of the vendor tampering with generation data.

Figure 3-4: Process Flow - Off-grid Vendor-based Centralized Monitoring System



3.2 COMPARITIVE ANALYSIS

The major difference between these two models relates to the method of data acquisition. The data acquisition system is vital to the success of the CMC system. The models are evaluated on the following parameters:

- Project cost
- Complexity
- Implementation time
- Scalability
- Data authentication
- Data security

Table 3-1: Comparison of Off-grid Facility-level Meter Integrated Centralized Monitoring System and Vendor-based Monitoring System

Parameter	**Option1:** Off-grid Facility-level Meter Integrated Centralized Monitoring System	**Option 2: Off-grid** Vendor-based Monitoring System
Project Cost	Requires meter (DLMS), data logger, communication system and subscription charges at each off-grid installation location. **Increases cost for this model**	Does not entail hardware and implementation costs at locations of off-site installations **Cost comparatively low**
Complexity	Requires hardware installation in the off-grid setup and establishing communication off-grid locations **Relatively complex**	No special hardware needs to be installed **Simple**
Implementation Period	Location of off-grid systems are spread across the state Will take longer time to implement	Relatively lesser time
Scalability	**Subject to network congestion of mobile network service provider**	**Easily scalable**
Data Authentication	No third-party devices are involved in off-grid facility level meter integrated centralized monitoring system solution **Source data from the off-grid site is reliable**	Susceptible to tampering of data as control localized. **Data authentication a problem. Can be addressed though audits**
Data Security	Absence of third-party interference **System more secure. Caution on web-based virus**	**Data needs to be scanned for any vulnerabilities**

3.3 SELECTION OF SUITABLE MODEL FOR CMC

In the case of Option 2, data authentication can be refined through a contract which legally binds the off-grid vendor to provide data at regular intervals, with access to source data for verification purposes. Further, for data authentication, an audit procedure can be initiated to verify the data received by the CMC system with the digitally available data at the servers of off-grid vendors. The establishment of the CMC is for monitoring purposes and not intended to link commercial conditions/payment obligations of the off-grid vendors. Hence, the chances of tampering of data by off-grid vendors may not be high. The system will deploy a web-based online user interface; hence a security solution to protect it from cyber-attacks will have to be incorporated in both models.

Based on an evaluation of both options, and the views of MPUVNL, it is recommended to establish the CMC through Option 2. All references, cost estimation, project specifications, etc., in Chapter 2 will relate to this option, i.e., **off-grid vendor-based centralized monitoring system**.

While in the present scenario MPUVNL has considered establishment of the CMC through Option 2, for future programs, Option 1, i.e., off-grid facility-level meter integrated centralized monitoring system may also be considered by other state agencies. In that case, while designing the program, it is recommended to include the necessary provisions and specifications of the CMC system, remote meters and data loggers in the program document, so that the implementation of Option 1 will be easier.

4 USER REQUIREMENTS AND FUNCTIONALITIES FOR CMC

This chapter provides details of the user requirements and project specifications for CMC. The project specifications cover the various functionalities of the CMC, its working process, and the scope of work of the off-grid vendor and CMC IT system developer in the establishment of the CMC.

4.1 FUNCTIONALITIES OF CMC

The main functionalities of the CMC as specified by MPUVNL are:

- Access to the generation data and status of individual off-grid installation
- Generation data to be made available as close to real time
- Regular updation of generation data of each off-grid system at a regular interval
- Representation of data in a user-friendly format (graphical/excel table)
- Options to classify the data based on off-grid vendor/district/type
- Large LED screen to display the user interface at MPUVNL
- Alarms, trends and reports from generation data
- Web-based user interface with the off-grid systems plotted on state map
- Admin interface for configuring/integrating data from new off-grid system
- Automated mail services for critical alerts
- Mail services for sending notification to off-grid vendor
- Scalable system to include the upcoming off-grid systems
- System security to protect from vulnerabilities

The off-grid vendor server should transfer the data of each off-grid system connected to it at a regular interval to the CMC system. The data will be sent through the advanced file transfer protocol that requires no human/manual intervention for data capturing. The CMC IT system developer should develop the solution for the data collection from different off-grid vendors' servers. The CMC server will check the file for any vulnerability, and collect and store the data in the database.

The CMC database can be accessed and presented through a web-based user interface. MPUVNL can access the data from any place using the internet. The user interface should have the facility to access operational data of all the off-grid SPV systems through an interactive state map. Multiple users can be defined with different levels of security to access the system. If any problem persists in any of the off-grid SPV systems, the same should be notified through an alarm and enable MPUVNL to intimate the same to the off-grid vendor. The CMC should be provided with automated mail services to certain users in MPUVNL who have the authority to take up critical issues with the developer. Regular standardized reports should be generated on daily, weekly and monthly basis. Based on certain criteria, users should have options to generate reports from the system.

4.2 MPUVNL'S REQUIREMENTS FOR CMC AND IMPORTANT DESIGN CONSIDERATIONS

For the installation of off-grid SPV systems, the central and state governments together provide financial assistance in the range of 30-50 percent of the project cost. MPUVNL, as the state nodal agency for program implementation, desires to monitor the performance of the off-grid SPV systems in the state. MPUVNL plans to establish the CMC for the purpose of monitoring.

4.2.1 Important design considerations for establishment of CMC

Key parameters to be considered for the system design include frequency of data collection, granularity of data, categories of user types for user interface, and the data transfer mechanism. Based on discussions with MPUVNL, the PACE-D TA Program team and a few off-grid vendors, the following outline has been considered for development of the CMC system.

Parameters to be monitored: The CMC system will monitor the DC Voltage, DC current and kWh reading from the meter connected between the solar panel and battery banks. For the hybrid off-grid systems, kWh readings of the Grid supply meter, AC Voltage, AC current and kWh reading of the meter connected to the load will also be monitored.

Frequency of data collection: Since the data transfer from the off-grid vendor's server to the CMC server will mean bandwidth charges to the off-grid vendor, the interval of transferring the generation report will be on an hourly basis[*]. The data transfer to the CMC system from different off-grid vendors is to be at different timings during the day, to avoid data transfer congestion. Each off-grid system would transfer data separately from the off-grid vendor's server to the CMC system in a comma-separated values (CSV) file format.

Granularity of data: The frequency of transfer of the generation report would be once in 24 hours, but the report should have generation details during the day on an hourly basis. This data will help the CMC system generate the trends for the different parameters and compare performance of the individual system with the standard performance.

Types of users and user interface: The main user of the CMC system is MPUVNL. The off-grid vendor should be able to access the CMS system to obtain details relating to their own systems. The public can provided with relevant, generic details online. The user interface, therefore, should have access control features such as separate login to cater to the different users. The user interface should have features of alarm, automated mail services on reports, etc.

Data transfer mechanism: No manual intervention should be involved in data collection and data analysis. The data transfer mechanism between the off-grid vendor's server and the CMC system should be automated, using any of the advanced secure file transfer protocols.

[*] Time to be finalized before tender specification for selecting CMC IT system developer

The summary of the important design considerations is shown in Table 4-1.

Table 4-1: Summary of Important Design Considerations

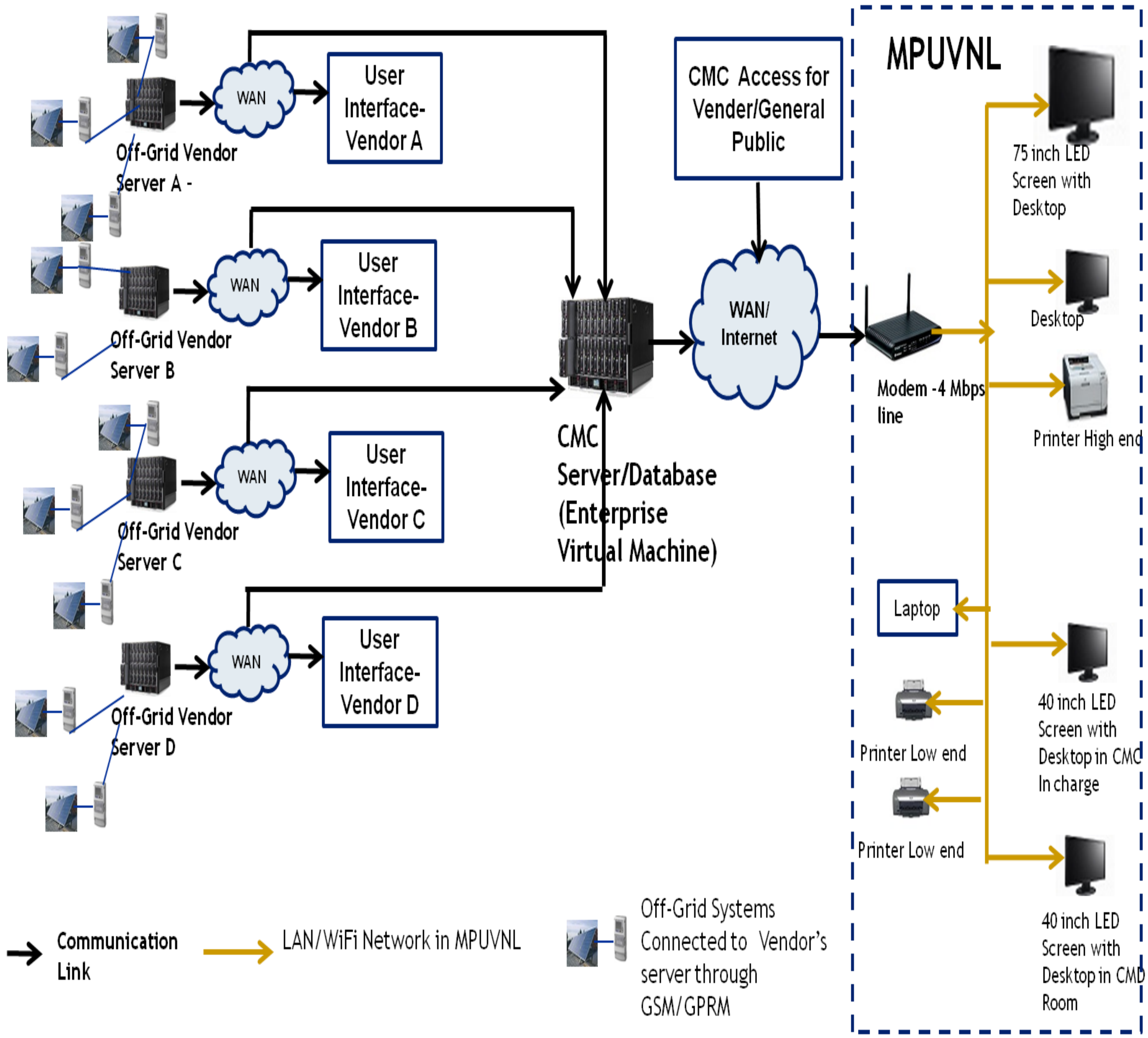
Sr. No.	Important Design Considerations	Details
1	Parameters to be monitored from each off-grid system	1. DC Voltage 2. DC Current 3. kWh reading of solar panel output 4.kWh reading from Grid supply meter 5. AC Voltage, AC current and kWh reading from the meter connected to the load
2	Frequency of data collection	Hourly Basis*
3	Granularity of data	Every 15/30/60 minutes (as feasible)
4	Types of users	MPUVNL Off-grid vendor General public
5	Data transfer mechanism	Automated advanced secure file transfer protocol

4.3 MODEL ARCHITECTURE OF CMC SYSTEM NETWORK

Model architecture for the network that defines the components and represents data flow in the CMC system is indicated in Figure 4-1. As mentioned in the architecture, different off-grid SPV systems are installed by off-grid SPV vendors. The meter connected to the data logger, draw data into their servers using GPRS or GSM, at regular intervals, for remote monitoring purposes. The SPV vendor server would then send the generation data to the CMC server at a regular interval. This communication will be through a TCP/IP protocol. The back-end and front-end support solutions for the CMC server will have to be developed by the CMC IT system developer.

* Time to be specified in the tender for selecting CMC IT system developer

Figure 4-1: Model Architecture of CMC System Network

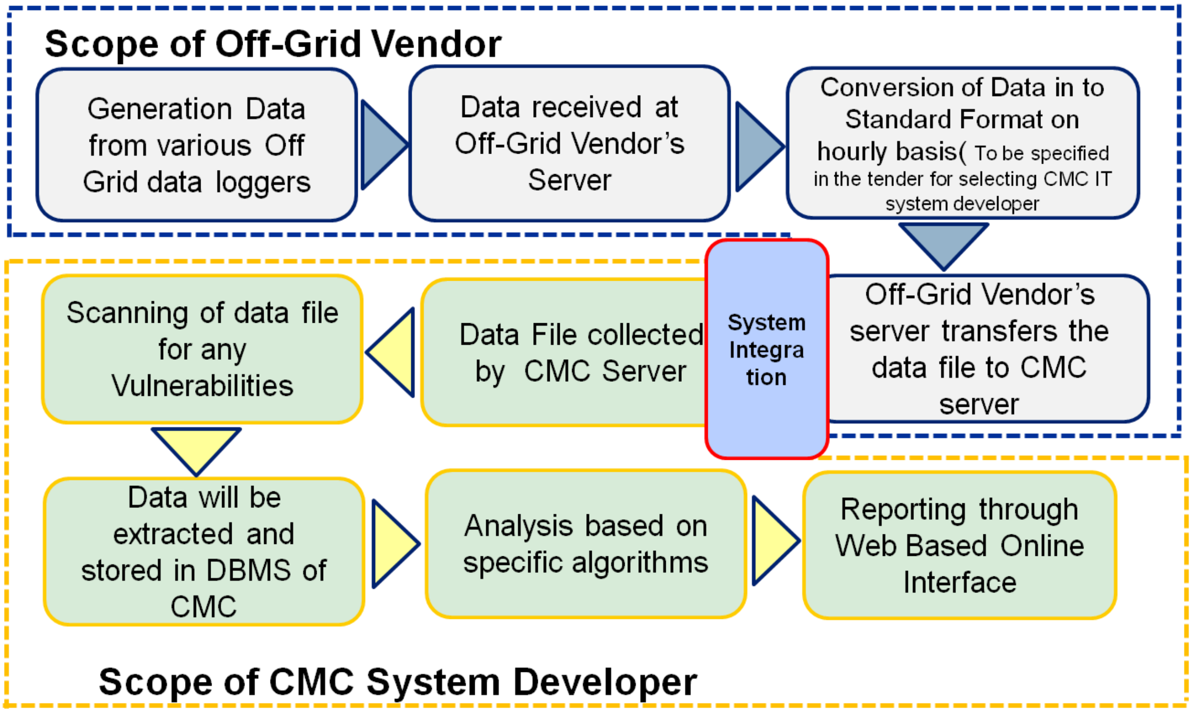


The user requirements for the user interface, database, model screens and appearance, and the system requirement are discussed in Chapter 5.

4.4 WORKING PROCESS OF THE CMC SYSTEM

The working process of the off-grid CMC monitoring system involves close coordination between the vendor's system and the CMC system to be established. The data logger and meter acquisition are in the domain of the off-grid vendor. Hence it is necessary to integrate the CMC system with the off-grid vendor's meter acquisition system. The working process of the system is shown in Figure 4-2.

Figure 4-2: Working Process of the System



4.4.1 Scope of work by off-grid vendor

As shown in Figure 4-2, the scope of work of the off-grid vendor is to obtain data from the off-grid meter, transfer the same into a standard format, and send it to the CMC server. Monitoring of real-time data will overload the network and could cause congestion in the system. Hence it is recommended that the off-grid vendor collects data and sends it at a regular interval of one hour*. The data must have 15/30/60 minutes (as feasible) of generation details for the one-hour period. The different vendors will send data at different scheduled times during the day.

4.4.2 Scope of CMC IT system developer

The CMC will collect data from the off-grid vendor's server, and scan it for any vulnerability. As the CMC server would be communicating to multiple servers, system security and firewalls would have to be strong enough to protect the CMC system from threats. Security is more than just user privileges and password policy. The database storage must be of adequate capacity to take care of new expansion over the next 10 years at the least. System security requirements are detailed in Chapter 5.

* Time to be finalized before the tender specification for selecting CMC IT system developer

A data analytics system will be developed by the CMC IT system developer. This system would process the data for easy access and classification of generation data based on various attributes - districts, developers, and type of system, aggregated at the state level.

The CMC would store the static data about the information relating to each off-grid SPV system such as installed capacity and date, owner, location, subsidy provided, etc. MPUVNL would provide the details of data and storage requirements to the CMC IT system developer during the system development. The system should have capacity to add the new upcoming off-grid SPV systems. The admin interface of the CMC should be enabled for any future expansion of off-grid SPV systems in the state.

4.4.3 Need for System Integration

System integration is the process of linking up different computing systems and software applications physically and/or functionally to work effectively as a whole. The system integrator brings discrete systems together through computer networking and programming.

Data acquisition is a subsystem of the CMC system, which needs to be integrated with the off-grid vendor’s database. Figure 4-2 shows the system integration needed for the functioning of the system. The CMC developer would build the solution based on Service Oriented Architecture (SOA) for enabling integration with other systems.

4.5 MODEL DATA COLLECTION FORMAT

The data needed for the CMC system can be classified as under:

- Base information about the off-grid SPV system
- Generation data for each off-grid SPV system at regular interval

4.5.1 Base Information of Off-grid SPV Systems

Before the development of the system, the base information of all the off-grid installations in the state would be collected manually in an excel sheet format. MPUVNL will circulate the format sheet to all off-grid vendors and the vendors would have to provide the specific details for the off-grid SPV system installations done by them, for each location. These details will be made available before the selection process for CMC system developer. This information would be stored in the CMC system as base information for each off-grid SPV system.

The information would cover the following details about the off-grid SPV system:

1. Location details including city/town, district
2. Latitude and longitude of the setup location
3. Details of ownership/developer/vendor with emergency contact numbers and e-mail id
4. Installed capacity of solar panel and battery banks
5. Type of off-grid system
6. No. of meters and its information related to type, manufacturer
7. Details related to type, manufacturer of data logger/data collection/server

4.5.2 Collection of Generation Data at regular intervals

The off-grid generation data which records periodic changes gets collected at the off-grid vendor's database. Once in an hour, the off-grid vendor's server should send the generation data with the 15/30/60 minutes (as feasible) generation data for the one hour period[*]. The model data collection format should be similar to one shown in Table 4.1.

As the CMC system will have to acquire data from multiple servers which have the generation data of multiple off-grid systems, it is necessary to provide a unique identification number to each off-grid SPV system. This would help identify the data and the off-grid system. The allocation of off-grid SPV system id is based on multiple attributes such as off-grid vendor, district, type of system, etc. The SPV off-grid system id would be indicated by the vendor while sending generation data and time stamp of the information.

Table 4-2: Model Data Collection Format

Off-Grid System ID*	Date (DD-MM-YYYY)	Reporting Time (HH:MM:SS) 24 Hour Format	Status On /Off	DC Voltage (V)-Solar Panel	DC Current - (A)- Solar Panel	DC meter Reading (kWh)	AC Incoming Meter Reading (kWh)	AC Voltage - Line Connected to Load (V)			AC Current - Line Connected to Load (A)			AC Outgoing Meter Reading (kWh)
								R	Y	B	R	Y	B	
MTBH010001	05-12-2014	09:00:00	Off	0	0	1270	500	415	410	412	10	9	12	1770
MTBH010001	05-12-2014	09:15:00	On	230	23	1290	510	415	410	412	13	12	10	1800
MTBH010001	05-12-2014	09:30:00	On	235	28	1310	518	415	410	412	13	14	12	1828
MTBH010001	05-12-2014	09:45:00	On	220	32	1333	522	415	410	412	10	10	10	1855

****Off-Grid System ID** |**Off-grid vendor's Code** MT- Multi Teach **|** **District Code** BH- Bhopal, **|** **Type of system** SA- Standalone, HS- Hybrid Single phase , HT- Hybrid Three phase*

Table 4-2 shows the model data collection format. During each hourly period, the off-grid vendor's server would send the data in such a format. The CMC database, would identify the generation data based on the off-grid system id in column one of the table.

This includes the developer's code, district code, type of off-grid and the serial number. For example, the system ID MTBHHS0001, shows that this system belongs to an off-grid vendor Multi Teach (MT), located in Bhopal (BH) and it is a Hybrid-Single phase (HS) off-grid system with serial no 0001. In this way any system can be identified or classified based on either off-grid vendor, district or by the type of the system. Based on the off-grid system id, the CMC database will store the data accordingly.

[*] Time to be specified in the tender for selecting CMC IT system developer

5 SYSTEM REQUIREMENTS AND COMPONENTS FOR CMC

5.1 USER ROLES AND ACCESS RIGHTS

The system will have the user interface that will be accessed by multiple users. Table 5-1 provides details on the different access rights of each user of the CMC system. Broadly the user modes can be categorized as follows:

1. User- Off-Grid SPV Vendor
2. User- Supervisor- MPUVNL Operator
3. User- Manager- MPUVNL
4. User- System Admin- MPUVNL/CMC IT system developer

Table 5-1: User Roles and Access Rights

Access Rights	User Modes			
	User- Off-grid vendor	User- Supervisor Operator MPUVNL	User Manager MPUVNL	System Admin- CMC IT system developer
Create/Add	No	No	Yes	Yes
Modify	No	No	Yes	Yes
Delete	No	No	No	Yes
Read Only	Yes	Yes	Yes	Yes
Assign/Revoke User Permissions	No	No	No	Yes
Addressing Alarm	No	Yes	Yes	Yes
Internal Mail Services	Yes	Yes	Yes	Yes

The user with login as System Admin will be authorized to assign the operation of certain functions, or features of functions, to specific user modes. MPUVNL will establish the privileges for each user mode. Each individual user will be assignable to one or more user modes. A mechanism for defining and controlling user access to the CMC system will be provided. Password security will be incorporated for access to the database, the system, the operating system, layered products, and other applications. Each password will be validated against the corresponding user information in the database. Users will have the ability to change their own passwords.

5.2 WEB-BASED USER INTERFACE

The user interface software will be based on state-of-the-art web-based technology to present interactive, full-graphics views of system data via LAN, corporate intranet or the internet. Since the solution should be cost-effective, the use of open source software to the maximum extent is recommended. A separate domain will be created for user interface through which users can access the user interface.

5.2.1 Displays

The user interface will have multiple displays:

1. Login Page
2. Home Page
3. Hierarchy Screen
4. Search Screen
5. Off-grid Details Screen
6. Report Section
7. Admin Page
8. Mail Services
9. Help

Display Requirements: The display should be compliant with the following requirements:

1. Interactive map in which all the off-grid systems should be plotted
2. Selection of an off-grid system for details
3. Selection of display from a menu
4. Cursor target selection on any menu, graphic, or tabular display
5. Selection of an alarm or event message
6. Selection of display by entering a display name or number
7. Forward and reverse paging in a page-based display
8. Selecting a previous display by re-call command

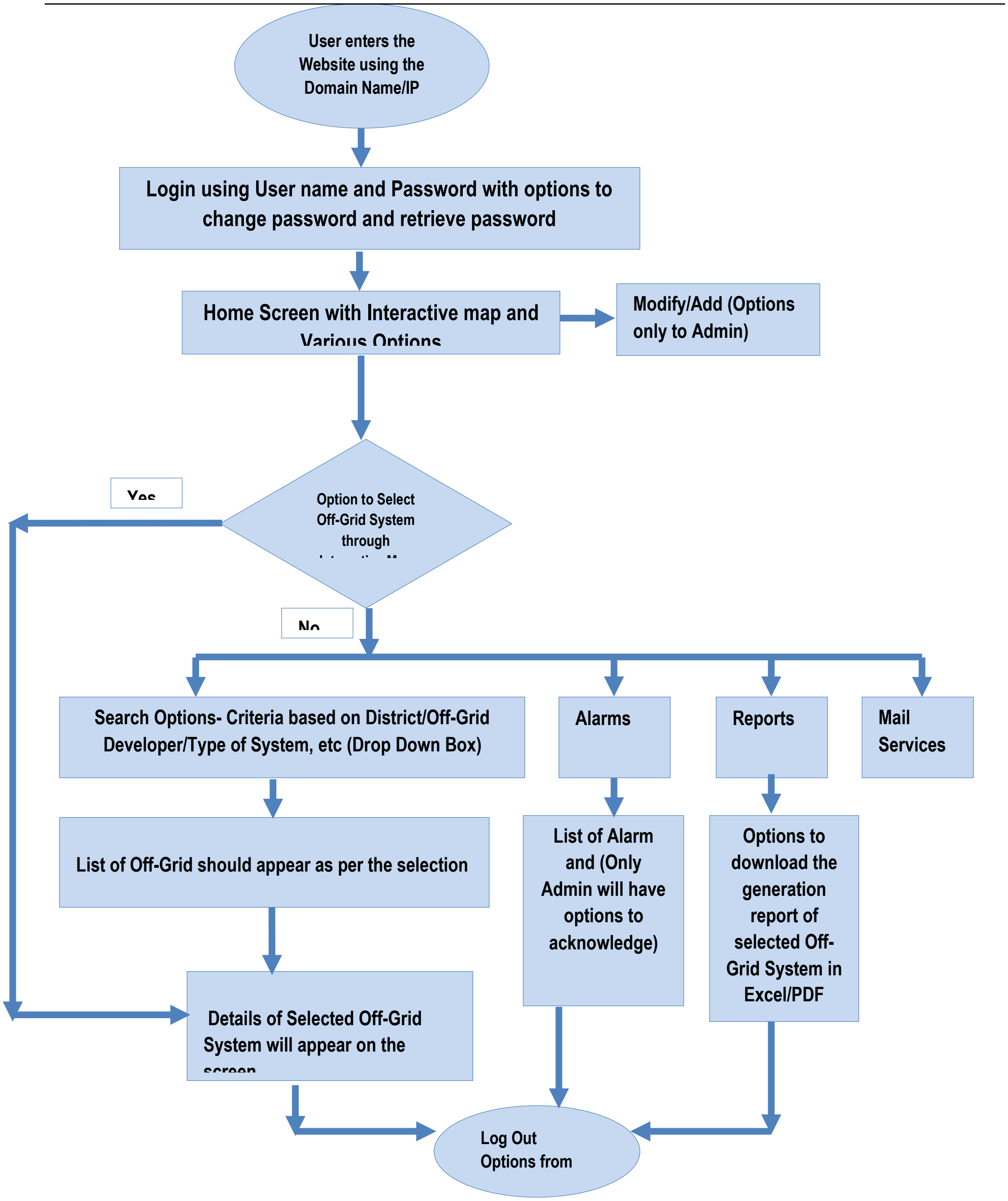
Permanent Marking: Some of the markings, including those listed below should be marked permanently in all the displays of the CMC system

1. Date and Time, with date in DD/MM/YYYY and time in HH:MM:SS format
2. Name of the CMC system
3. User Name and provisions for Logout from the system

User Help and Guidance: The Help menu will present a list of topics available for reference. The topics will refer to the CMC system user documents. The ability to scroll through the topic's explanatory text will be supported. The user will be able to scroll through this text. Exit from the Help menu will return the user to the same point in the sequence from which help was requested. The Help function should be context sensitive, in which one can automatically choose from a multiplicity of options based on the current or previous states of the navigation.

The user can interact with the CMC system through displays and list of menus provided in the system. The user should be able to select any off-grid SPV system, with a sorting provision based on the off-grid district, developer and type of system. If the user wants to directly see the brief details of any of the off-grid SPV systems, it should be possible by clicking the mouse on the desired off-grid SPV system on the map. To find more details on an off-grid SPV system, a user would just have to click on the particular system id or icon on the display. The navigation of user interface is shown in **Error! Not a valid bookmark self-reference.**.

Figure 5-1: Navigation of User Interface



5.2.2 Model Screens showing form of CMC User Interface

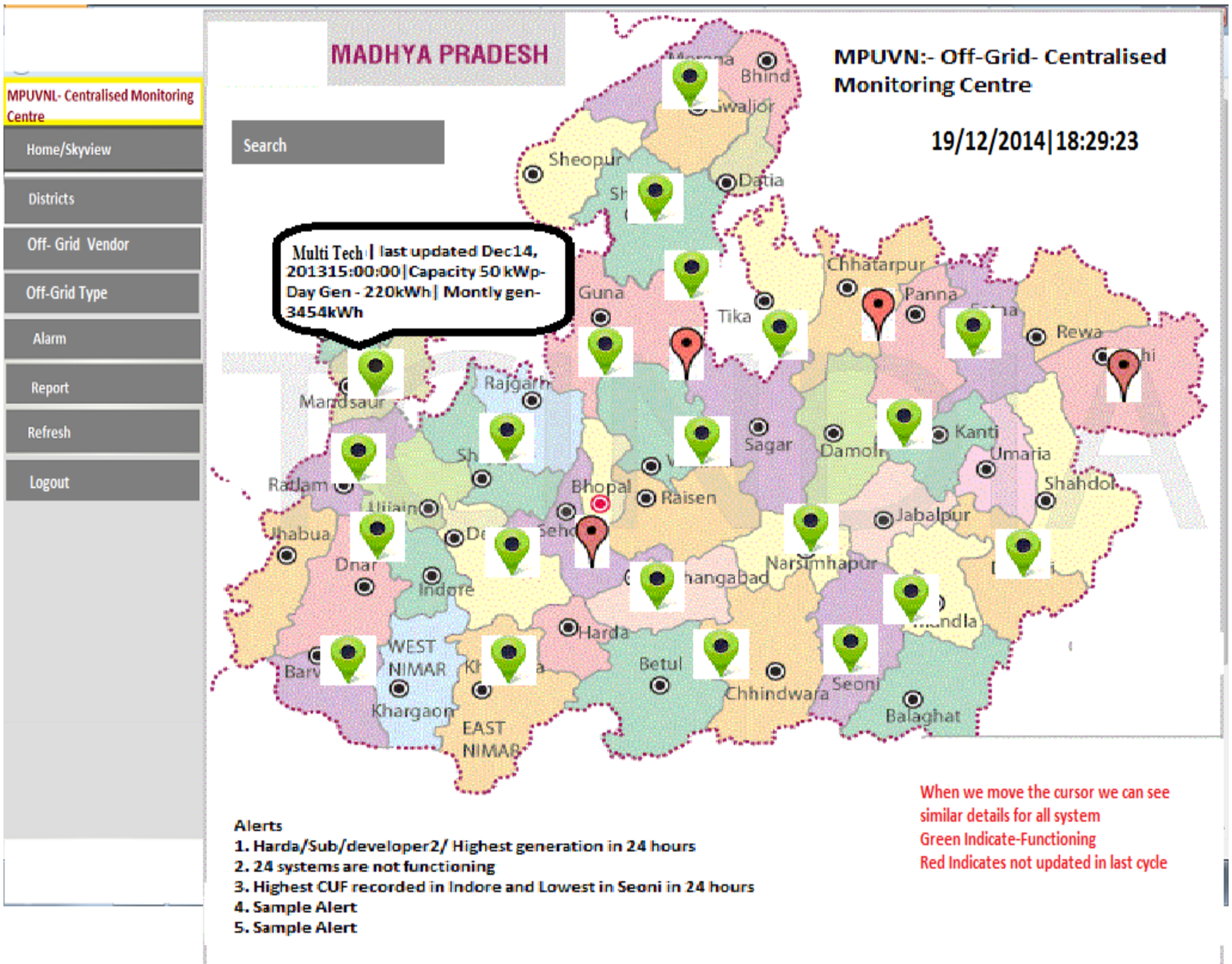
Login Page for CMC Application: The CMC system will be logged in through the user name and password provided. The sample login page will be as shown in Figure 5-2.

Figure 5-2: Model Login Screen for CMC Application

Some of the general information about the off-grid systems can be made available to any member or citizen. To access, no login credentials are required. Whoever wants to access the general information can click on the button 'General Information'. The information would relate to generation performance of off-grid systems, single line diagram of the system, sample photographs of the site, specific details on the equipment used, etc.

Home page of CMC: Once the user successfully logs in, the home page will appear showing the interactive map of Madhya Pradesh with the sky view location of off-grid installation. Please see Figure 5-3 for the model home page screen.

Figure 5-3: Model Screen for Home Page

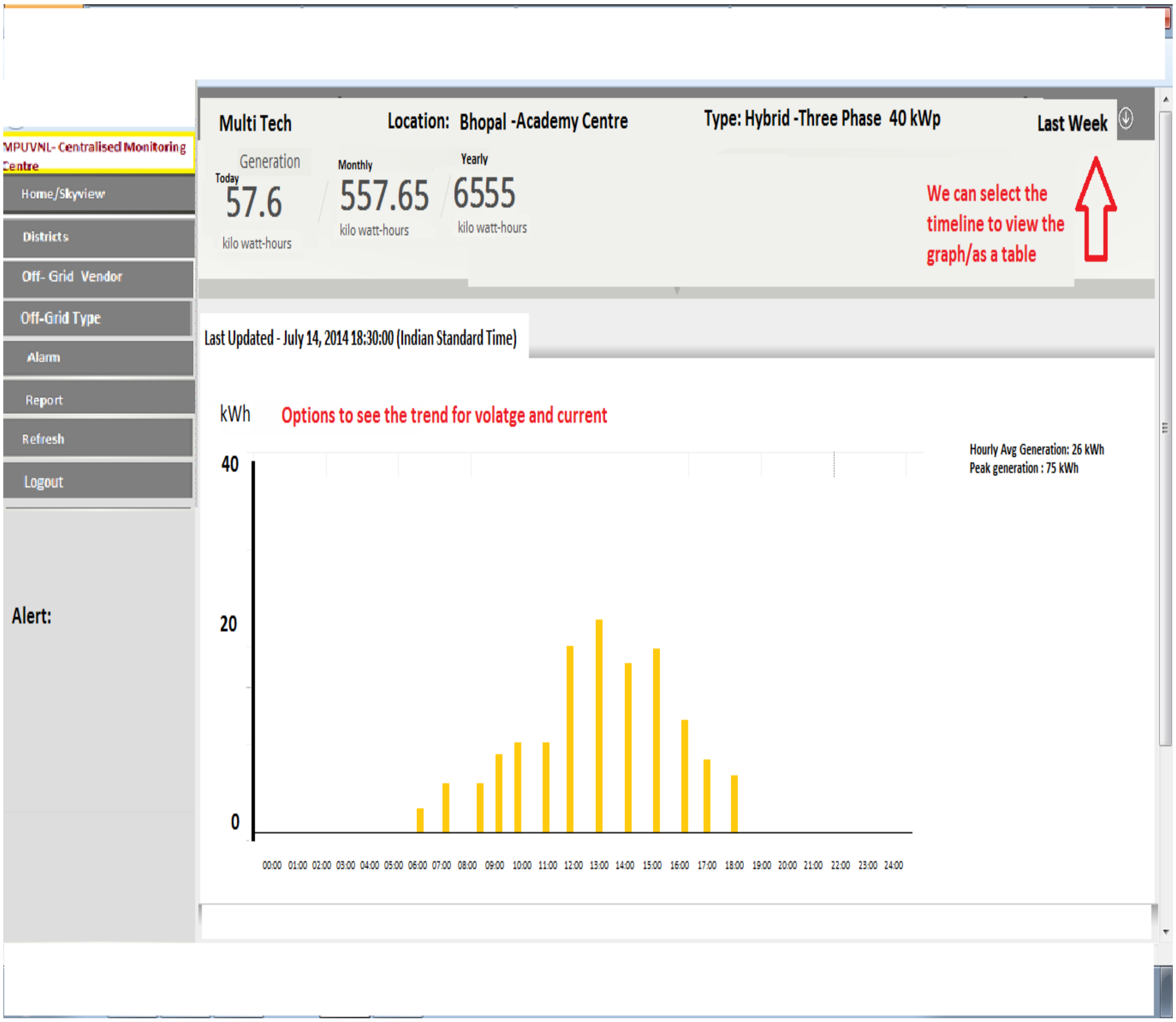


To find brief details on an individual off-grid system, the user can simply click on the off-grid system icon plotted on the map. The green indicator shows that the off-grid system was healthy during the last update while the red indicator shows that the system was not functioning during the last update.

This page will have additional tabs to see the off-grid system details, based on the category of off-grid vendors, districts, type of off-grid system, etc. Smooth navigation from the home page to all other pages would be possible.

Details of Individual Off-grid Systems: The links available on the map for each off-grid system would navigate the user to the individual off-grid system page. In this page all the details of the selected off-grid system can be viewed. Please see Figure 5-4 showing the model screen for individual off-grid systems.

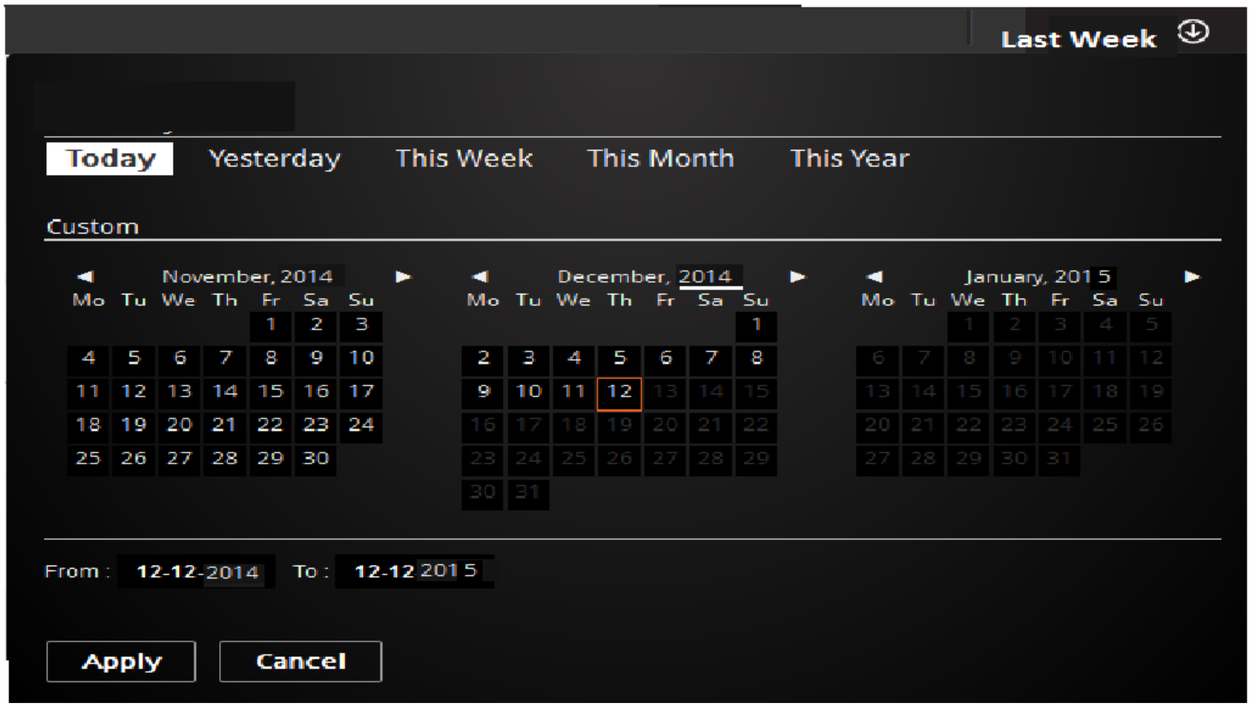
Figure 5-4: Model Screen-Individual Off-Grid System



Here the hour-wise generation details have been provided in a bar graph. By default the kWh reading of solar panels will be seen as a trend. Options will be available to the user for changing the trend for voltage, current and kWh reading of other meters of the system. Alerts or any other events for this system would be displayed on the screen. By default this will provide the generation details for the past 24 hours. The users can change the range by selecting the top end of the screen. Once this screen is clicked on, the data screen will appear. Please refer

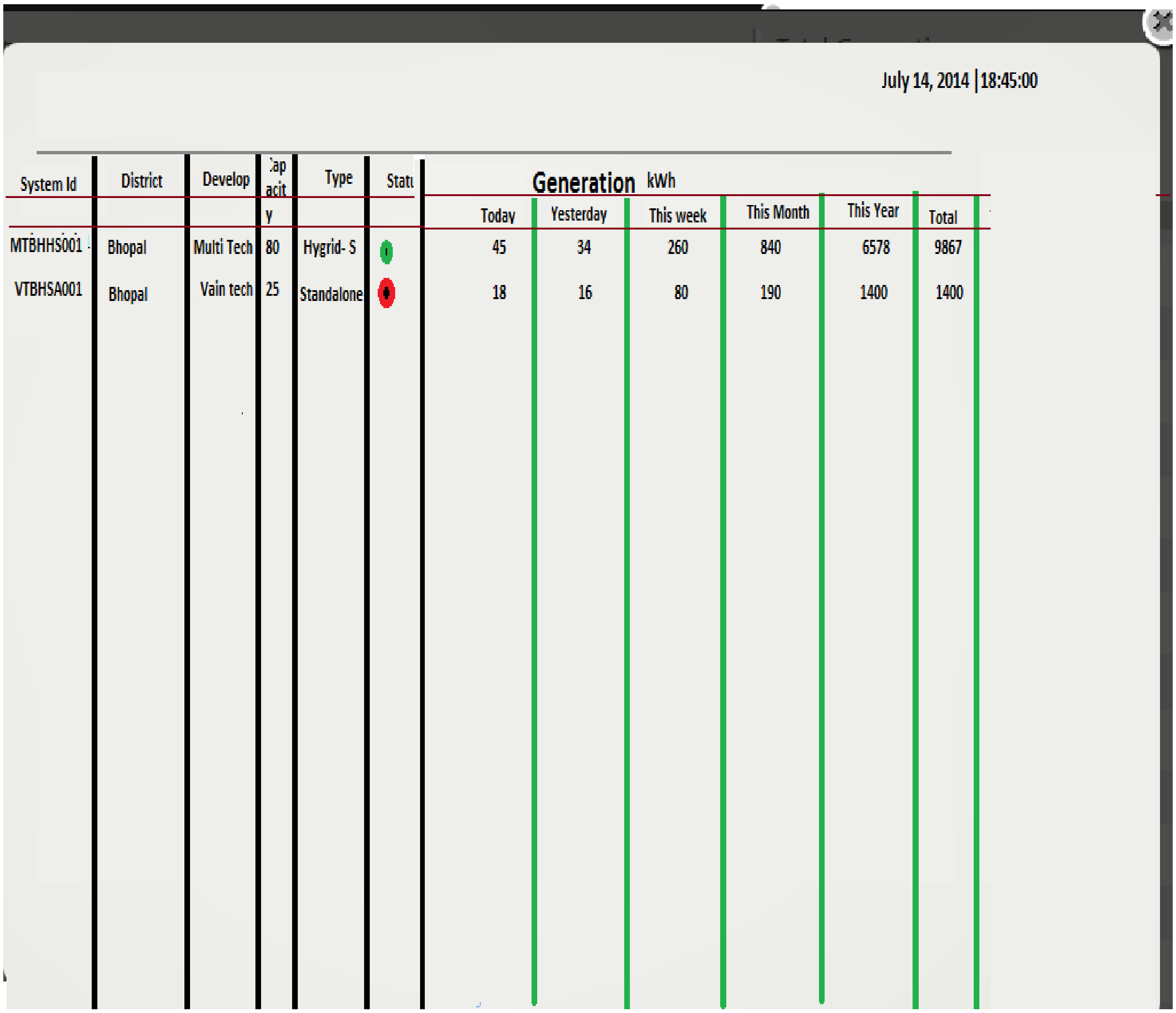
Figure 5-5 for the data selection screen. Here the user can enter the range of date and correspondingly the generation data will be available on the screen.

Figure 5-5: Model Screen- Date Selection



Selection of Multiple Off-grid systems: The search option tab allows the user to select any number of off-grid systems and the captured details will be visible in a single page. Please refer to Figure 5-6, in which the details of two off-grid systems are available in response to user requests.

Figure 5-6 - Model Screen for Multiple System Details



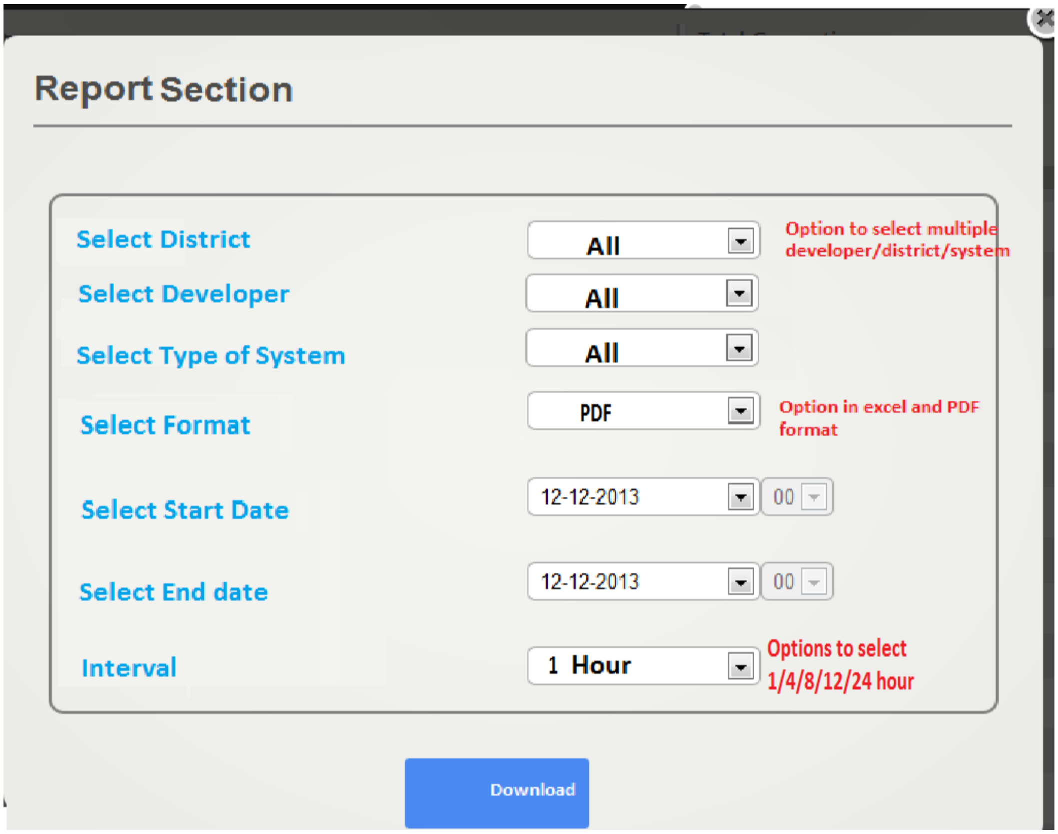
July 14, 2014 | 18:45:00

System Id	District	Develop	:ap acit y	Type	Statı	Generation kWh Today	Yesterday	This week	This Month	This Year	Total
MTBHHS001	Bhopal	Multi Tech	80	Hygrid- S		45	34	260	840	6578	9867
VTBHSA001	Bhopal	Vain tech	25	Standalone		18	16	80	190	1400	1400

This page will provide the macro level generation of each system. The user can navigate to the individual system details by clicking on the system ID.

Report Generation: The details of generation of all the off-grid systems can be downloaded as a report. Options will be available to download the report in multiple formats like excel, PDF, etc. Figure 5-7 shows the model screen on report generation.

Figure 5-7: Model Screen- Report Generation



In this page there are seven attributes which need to be specified by the user. The first three attributes provide the option to the user to select the off-grid system. The fourth attribute provides the option to select the format of the report that needs to be generated. Reports can be generated as Excel, PDF or CSV files. The next two attributes are to indicate the time period for which the report needs to be generated. The last attribute is for selecting the interval. The minimum interval is 15 minutes and the maximum interval is 24 hours.

5.3 HOSTING OF DATABASE

The database of the CMC should be based on state-of-the-art technology in order to be dynamic and reliable. There are two ways to establish the database: the traditional method of setting up an in-house server in the premises of MPUVNL; or to use cloud-based services for the database.

The following factors need to be considered while selecting the database:

- Scalability
- Security
- Reliability
- Power Backup
- Accessibility

- Disaster Recovery

Refer Table 5-2 for the comparative analysis between the cloud-based services and in-house services.

Table 5-2: Comparison of Cloud-Based Database and In-house Database

Factors	Cloud-Based	In-house
Scalability	Unlimited, and we can increase the capacity progressively	Limited scalability
Downtime during Scalability	No downtime	Downtime required
Security	Highly secured	Less secured
Maintenance Engineer	Not required – will be taken care of by data centre	Required
Connectivity	All-time connectivity, can be accessed from anywhere through internet	Depends on the maintenance
Power Backup	Not required	Required
Disaster Recovery	Data center has the provision for disaster recovery	Will be costly, if separate disaster recovery is required
Capital Cost	Payment on actual usage	Fixed, High

From the comparative analysis, it is evident that the cloud-based services are better than the in-house server. Most IT solution providers are moving towards cloud-based services. Hence, the database of CMC could be set up in a cloud. Several data centers provide such services. The cloud services will be procured from the III-tier data center, which should be compliant with the following functional requirements:

i. **Scalability:** The data center should provide the maximum scalability with multilayer architecture. The services provided must be reliable and transparent. It should be possible that the database can be increased without any system downtime and loss of data.
ii. **Security:** Provision of world-class security at every level. Security comprises physical security, network security, application security, internal systems, etc.
iii. **High Availability:** The data center should have secured and continuous operations, network capability, with reliable backup for data and power.

The Madhya Pradesh State Data Centre (MPSDC) located in Bhopal provides Tier-III equivalent services, which include servers, storage, connectivity, reliable hosting, backup and disaster recovery. Hence, MPSDC can also be considered as an option while selecting the cloud-based database service provider.

Refer **Annexure III** for more information on cloud computing services.

5.3.1 Database Management System:

The type of DBMS is dependent on the method of structuring the database. The advanced and sustainable method is to store the data in XML format. This format is easy to read and understand, and can be processed easily by computers. It is platform independent, vendor independent, system independent and can be integrated with any other applications. In future if the CMC application has be developed or upgraded to any other advanced application, the historical data stored in XML format can be easily imported into the new system. There will not be any loss of data in the transition. XML uses the Common Component Architecture or CCA, and the Common Object Request Broker Architecture. In other words, this means that it uses a common and standard protocol, which helps inter-operability for programs. XML's efficiency and accuracy, when it comes to data, has a proven track record.

5.3.2 Data Flow:

The CMC system will consist of data flow starting from the meter installed at the off-grid system to the user interface of the CMC system. The step-by-step data flow in the CMC system is as follows:

Data flow within off-grid vendor's scope

- Step 1: Data measured by the meter installed at the off-grid systems
- Step 2: Data collected by data logger through RS 232/RS 485 port and stored
- Step 3: Data transferred through GPRS/GSM mode of communication to the corresponding off-grid vendor's server at a regular interval
- Step 4: Generation data gets stored in the database management system of off-grid vendor's server
- Step 5: Once in an hour, the off-grid vendor's server transfers the complete set of generation-related information to the CMC server through TCP/IP protocol.

Dataflow for Interface with CMC System

- Step 1: CMC server receives the data from different off-grid vendors' servers and stores it in its database
- Step 2: Analysis of the data using specific algorithms
- Step 3: Data presented to the user through the user interface

5.4 CMC APPLICATION

The CMC IT systems developer is expected to develop the system design and development based on the functionalities of CMC as discussed earlier. All the software provided by the CMC IT system developer, including the operating system, database management system and support software, must be from reputed national and international organizations and will comply with the industry-accepted software standards. In applications where no standards are set nationally or internationally the software will comply with those widely accepted de-facto standards put forth by industry consortiums such as Open Source Foundation (OSF). The CMC IT system developer should maintain the open system objective, promoted by industry standards groups by using software products that are based on open standards.

All the CMC applications will be maintained by MPUVNL using the supplied software utility and documentation. The software design and coding should address the following requirements:

i. **Expansion and Integration:** Software should be dimensioned to accommodate the future expansion in the number of off-grid SPV systems. This software should be able to integrate with other software applications (if any) in the future.

ii. **Modularity:** The software should be modular, and not complex, so any changes in the program can be implemented by the programmer without much difficulty, in a minimum time period.

iii. **Execution Time**: The user requests should be executed in the minimum time and query search should be fast. Any process that takes abnormal time should get aborted automatically and a proper notification/ display message sent to the user interface.

iv. **Programming Language:** The software will be written in any IEEE standard programming languages. This should run on any system without need for any major changes. The software should be on Service Oriented Architecture (SOA) which is a software design and software architecture based on discrete pieces of software providing application functionality as services to other applications. It is independent of any vendor, product or technology.

v. **Portability and Inter-operability:** The software will be designed to the extent possible for hardware independence and operation in a network environment that includes dissimilar hardware platforms. The system services software will be built on open standards.

vi. **Time Recording:** The CMC system will maintain time and date for use by various software applications. The GPS-based time receiver will be used for synchronizing the CMC system time. All servers and operator workstation clocks will be synchronized within the accuracy of +/-500 milliseconds.

vii. A surge protection system is required to protect the system from disturbance caused by lightning, etc.

Benefits of SOA: The reality in any enterprise is that infrastructure is heterogeneous across operating systems, applications, and system software. Some existing applications are used to run current business processes, so starting from scratch to build new infrastructure is not an option. Enterprises should respond to business changes with agility; leverage existing investments in applications and application infrastructure to address newer business requirements; support new channels of interactions with customers, partners, and suppliers; and feature an architecture that supports organic business. SOA with its loosely coupled nature allows enterprises to plug in new services or upgrade existing services in a granular fashion to address the new business requirements, provides the option to make the services consumable across different channels, and exposes the existing enterprise and legacy applications as services, thereby safeguarding existing IT infrastructure investments. SOA is independent of any vendor, product or technology. The main benefit of SOA is that it allows simultaneous use and easy mutual data exchange between programs of different vendors without additional programming or making changes to the services. These services are also reusable, resulting in lower development and maintenance costs, and providing more value once the service is developed and tested.

5.5 COMMUNICATION AND SYSTEM SECURITY

The CMC system should be augmented with proper communication and networking channels, so that users can be connected with all applications through an uninterrupted link. The network communications software will use a standard protocol such as TCP/IP. The software will link dissimilar hardware nodes, including local and remote workstations, application servers, communication servers, and peripherals like printers into a common data communication network, allowing communications among these devices. The communication link would be supported by sufficient, dedicated broadband bandwidth, so that the user can access the system without any interference. Comprehensive network security solutions will be put in place. Security is more than just user privileges and password policy. Security encompasses physical, systems security, application, network security, and data security. The system will be protected by a multilayered firewall which protects the complete network from cyber intrusion. Separate firewalls of different OEMs will be provided to take care of the security of all the desktops. The firewall to protect the system should have the following features:

1. Intrusion prevention system, network-based
2. Capability of working in load sharing and hot standby mode
3. Sufficient speed
4. Denial of service prevention
5. JAVA and ActiveX blocking
6. Inspection for web, mail, SQL application, etc.
7. Detailed system logging and accounting feature
8. The data will be encrypted wherever supported by existing systems/devices/technology
9. Identity and access management system, which will control and log the access control of all users of the CMC systems
10. Enable creation and maintenance of accounts, passwords and functionality access levels, along with log details

6 STAKEHOLDERS - ROLES AND RESPONSIBILITIES FOR CMC IMPLEMENTATION

The main stakeholders involved in the development of the CMC system are:

1. MPUVNL
2. PACE-D TA Program
3. CMC IT System Developer
4. Off-grid Vendor

6.1 MPUVNL

MPUVNL will hold the ownership of the CMC system; hence the role of MPUVNL in the establishment of CMC is very important. The CMC system will facilitate MPUVNL in monitoring all the off-grid SPV systems installed at different locations in the state of Madhya Pradesh. MPUVNL would be responsible for the following, in the development of the CMC system:

i. **CMC Functionalities:** MPUVNL has to define the user requirements, based on which the CMC functionalities will be defined. The user requirements include the data to be monitored for each off-grid system, the interval of data logging, etc. The user requirement will form the basis for the CMC IT system developer to design and develop the CMC system.

ii. **Details of Off-grid SPV Systems:** The number of off-grid SPV systems, location, and ownership determine the extent of data flow in the CMC system. Since the system will communicate with multiple servers owned by different off-grid SPV vendors, the CMC system developer would need the details of these servers, including their communication protocol. Before floating the bidding document for the CMC system developer, these details should be available to the bid participants.

iii. **Commitment from Off-grid Vendor:** The CMC system will collect the off-grid generation data from different servers of vendors. The SPV data must be sent by the off-grid servers in the prescribed format to the CMC server, in an automated way. At present, there is no contractual binding on off-grid vendors for sending the authenticated generation data in an automated way at regular intervals. Since this is the heart of the system and to avoid any uncertainty in the CMC system development, MPUVNL should seek contractual commitment from the off-grid vendor to make available their generation data. The data transfer should be uniform for all (existing and future) off-grid SPV systems.

iv. **Funding Arrangement:** The CMC system will be developed by the CMC IT system developer and there is cost involved in the development. MPUVNL will arrange the necessary funds required for the project and would seek budgetary sanction for the CMC system. During the development of the CMC system, MPUVNL should disburse the funds to the CMC IT system developer as per the agreed terms and conditions executed in the contract.

v. **Selection of CMC System Developer:** To select the CMC system developer, MPUVNL needs to follow the tender process and would be required to float a Request for Proposal (RfP). MPUVNL, with assistance from the PACE-TA Program, would prepare the RfP and subsequently a pre-bid meeting would be conducted for the prospective bidders. Based on the pre-bid meeting discussions, the RfP would be finalized and further tender process undertaken. Based upon technical and financial evaluation of the bidders, the CMC IT system developer would be selected by MPUVNL and a formal contract would be signed between both parties.

vi. **Monitoring of CMC Developer's Activities:** MPUVNL, with support from the PACE-D TA Program, would monitor the activities of the CMC IT system developer during the development and implementation phase. Based on the feedback from the program team on the progress of system development, MPUVNL would take necessary action and facilitate/direct the CMC IT system developer for timely implementation of the CMC.

vii. **Training on CMC System:** After the development of the CMC system, the CMC IT system developer would provide training to the MPUVNL staff on the usage and operation of the system. MPUVNL should designate their staff to attend the training and takeover of the system from the CMC IT system developer.

6.2 PACE-D TECHNICAL ASSISTANCE PROGRAM

USAID has initiated the PACE-D TA Program in India with the objective of accelerating clean energy deployment via robust sets of policies and regulatory measures, knowledge exchange and pilot projects. The program provides a platform to public and private stakeholders to develop, test, validate, and commercialize innovative technologies for the growing low-carbon market. It also program provides support to stakeholders on scaling up of RE technologies. In this regard, Madhya Pradesh has been identified for focused technical assistance under the PACE-D TA program for institutional, policy and regulatory support in the RE domain. MPUVNL was identified as the beneficiary organization for technical assistance in Madhya Pradesh. MPUVNL is the state nodal agency for development of off-grid RE with the mandate of implementing all the schemes sponsored by MNRE.

The first activity under the PACE-D TA Program for MPUVNL is to provide assistance in setting up the CMC. The following are the list of activities for which PACE-D TA Team is extending support to MPUVNL in establishing the CMC.

i. **Preparation of Detailed Project Report:** The Detailed Project Report (DPR) for the CMC system would be the first and foremost step in the development of the CMC. The conceptualization of the CMC system and the evaluation of options available in system would be clearly defined in the DPR. It would cover details of the project, its budgetary cost of estimation and the roadmap for setting up the CMS system. The DPR would be helpful to MPUVNL to arrange funds for the project. The PACE-D TA Program team will study the existing system in MPUVNL, prepare the DPR and suggest the best possible solution to establish the CMC system.

ii. **Tender/RfP Preparation:** The program will also provide support to MPUVNL in preparing the RfP/Tender documents for the bidding process to select the CMC IT system developer.

iii. **Bid Process Management:** The program will support MPUVNL in conducting the pre-bid meeting to clarify the queries from the bidders about the project. Subsequent to the pre-bid meeting, if amendments are necessary in the RfP document, the program team would help in the process. The team would help MPUVNL in evaluating the technical proposals from bidders and guide MPUVNL in selection of the appropriate CMC IT system developer.

iv. **Project Management and Facilitation Support:** The PACE-D TA Program will provide support to MPUVNL in monitoring the progress of work by the CMC IT system developer and would caution MPUVNL in case of any deviation or delay in the work of the developer. The program team will participate in the steering committee meetings on the project and facilitate the implementation of the CMC system. Further, it would assist MPUVNL in the user acceptance testing of the CMC system.

6.3 OFF-GRID VENDOR

There are 123 off-grid SPV systems (as of January 2014) set up by different off-grid vendors located in different parts of the state. As the data collection system from the off-grid system lies within the control of the off-grid vendor, the role of the latter in the working process of the CMC system is important and of long-term significance.

i. **Providing detailed information about off-grid SPV system:** The off-grid vendor should provide the information of their off-grid SPV system in the prescribed format and details. MPUVNL would circulate the data template in which the vendor needs to provide the details of their system.

ii. **Automated data sending mechanism:** The off-grid vendor should enable its server to send the authenticated generation data to the CMC system at regular intervals. For each off-grid SPV system, the data should be sent in a uniform format, which will be suggested by MPUVNL. The data would be transferred at regular intervals (say, one hour)*. The granularity of generation data would be to the extent of 15 minutes. During the working process, if any of the off-grid system data is not transferred to the CMC system, MPUVNL would alert the off-grid vendor. The latter should rectify the problem and make sure that the system functions properly.

iii. **Coordination in CMC system development:** It is the off-grid vendor's responsibility to provide the generation data to the CMC system. In the course of development of the CMC system, the vendor should provide necessary co-operation, support, access to its server information and facilitate dialogue with its IT experts. Whenever required, the system should be checked for efficiency and reliability. It is also necessary for the off-grid vendor to coordinate with other stakeholders involved in the development.

6.4 CMC IT SYSTEM DEVELOPER

The CMC IT system developer would be selected by MPUVNL through the bidding process. The successful bidder would develop the CMC system as per the requirement from MPUVNL. The following are the roles and responsibilities of the CMC IT system developer:

i. **System requirement document:** The success of the project lies in the hands of the system developer. First the developer needs to understand the user requirements. The CMC system developer will prepare the system requirement document and seek its approval from MPUVNL before starting its development. This document will serve as the base document, so that any deviation from the scope of work of the CMC system developer can be easily identified.

ii. **System development:** The CMC IT system developer would design and develop the CMC system. It would be responsible for procuring the necessary hardware and software required for the CMC system, in consultation with MPUVNL. The necessary programs to operationalize the functionality of the system are to be developed, and the smooth operation of the system tested, on a test bed, by the developer. On the test bed, they have to demonstrate the connectivity of ten percent of off-grid systems belonging to different off-grid vendors. Once the test bed performance is deemed satisfactory, the system has to be scaled up to include all the off-grid SPV systems in the state. MPUVNL, with the support of the PACE-D TA Program, would monitor the developer's project activities and the system performance.

iii. **User Manual and Training:** Once the system is developed and starts functioning smoothly, it would be handed over to MPUVNL. The CMC system IT developer will prepare the operator and administration manual for the system and would provide a week-long training on the operation of the CMC system to the MPUVNL staff.

* Time to be finalized before the tender specification for selecting CMC IT system developer

iv. **Maintenance of the system:** The CMC IT system developer would be responsible for the maintenance of the system for a minimum period of say, three years. For this initial period, MPUVNL will not bear any cost toward the maintenance. The maintenance and spares costs are to be included in the project cost and the same will be disbursed to the CMC system developer at regular intervals.

7 BUDGETARY COST ESTIMATION FOR CMC

The expense to be incurred for the CMC system development and implementation can be related to two distinct phases. The first phase is the development phase where CMC system development takes place, involving, predominantly, a one-time capital expenditure. During the maintenance phase, where support for operating the CMC system is required, recurring expenditure in the nature of manpower, communication, maintenance, etc., needs to be provided for.

7.1 DEVELOPMENT PHASE

For the development of the CMC system, certain hardware, software, networking and communication facilities would be necessary. The CMC IT system developer would be incurring certain implementation charges too.

Hardware: The following are the components needed for the development of the CMC system:

i. **One 75-inch LED Screen**- This is a standard 75-inch LED screen with minimum one HDMI, RF, USB, PC port, LAN port and inbuilt speakers. This will be installed in the CMC monitoring center. A desktop computer would be connected with the LED screen to deliver data through the user interface.

ii. **Two 40-inches LED Screens**- This is a standard 75-inch LED screen with minimum one HDMI, RF, USB, PC port, LAN port and inbuilt speakers. One screen will be installed in the CMC room of MPUVNL and the second in the cabin of the CMC in-charge.

iii. **Three Desktops**- The screen is connected to a desktop, which brings the user interface to the screen through the Internet. The minimum configuration of the desktop should be i3 processer 500 GB HDD, 8 GB RAM, with a LAN port, CD Drive, Mouse, Keyboard, etc.

iv. **One Operator Desktop**- This desktop would be located in the CMC for use by the operator who monitors the CMC system. The minimum configuration of the desktop should be i3 processer 500 GB HDD; 8 GB RAM, with LAN port, CD Drive, Mouse, Keyboard, etc.

v. **High End Printer**- This printer would be located in the CMC. The minimum requirements of the printer: automatic document feeder and ethernet port, print black and white, minimum print speed of 40 pages per minute, color scan, copy, and fax functions.

vi. **Low End Printer**- This printer would be connected to the system located in the office of the CMD and the CMC in-charge, and will be connected to the CMC network. The minimum requirements of the printer are color print and scan, copy and fax, with printing speed of 20 pages per minute.

vii. **Power Backup Facility**- This is a handy **UPS system,** which will provide power backup facility to the CMC for a minimum period of five hours; the UPS system would use lithium ion batteries and be maintenance-free.

Table 7-1 shows the estimated cost of the required hardware components.

Table 7-1: Estimated Cost of Hardware

Cost Component	Description	No. of Units Required	Cost per unit in Rs.	Total Cost in Rs.	Remarks
LED Screen in CMC	Standard 75 inch LED screen with minimum one HDMI, RF, USB, PC Port, LAN port and inbuilt speakers	1	250,000	250,000	Details for LED TV Manufacturer's website
LED Screens in cabin of CMD/CMC In-charge	Standard 40 inch LED screen with minimum one HDMI, RF, USB, PC Port, LAN port and inbuilt speakers	2	40,000	80,000	Details for LED TV Manufacturer's website
Desktop	4 GB, i3, 500 GB HD, 8 GB RAM, with LAN port, CD Drive, Mouse, Keyboard	4	35,000	140,000	Details for Laptop/Desktop Manufacturer's website
Laptop	4 GB, i3, 500 GB HD, 8 GB RAM, with LAN port, CD Drive, Mouse, Keyboard	2	40,000	80,000	Details for Laptop/Desktop Manufacturer's website
Printer- High End	Laser 4-in-one: Print, Copy, Scan and Fax, 50 Sheet Automated Document Feeder, Multi Tray, built-in 10/100 Base-T Ethernet port with USB enabled, Minimum 40 ppm (Black and White)	1	80,000	80,000	Details for printer Manufacture's website
Printer- Low End	Desktop printer, 20 ppm, Colour, USB Enabled	2	10,000	20,000	Details for printer Manufacture
Electric Cables, Spike buster	As required for Connectivity	As required		10,000	Estimated
UPS for the CMC	Minimum 5 hour backup	As required		50,000	Estimated
Total Cost of Hardware in Rs.				**710,000**	

Infrastructure: The basic infrastructure needed for the CMC system includes the furnishings, fixtures, and air-conditioning facility. Table 7-2 shows the estimated costs for the infrastructure of the CMC system.

Table 7-2: Estimated Cost of Infrastructure

Cost Component	Description	No. of Units Required	Cost per unit in Rs.	Cost in Rs.	Remarks
Furnishings and Fixtures	Chairs, Tables , and indoor accessories	As required		150,000	Estimated
Air Conditioning facility	1.5 ton Split Air Conditioner	2	40,000	80,000	Estimated
Other Miscellaneous Charges	Racks for keeping documents			40,000	Estimated
Total cost of Infrastructure in Rs.				**270,000**	

Software: The cost for the software components includes the cost of licenses required. Table 7-3 shows the estimated cost for the software.

Table 7-3: Estimated Cost of Software

Software Component	Description	No. of Units Required	Cost per unit in Rs.	Cost in Rs.	Remarks
DBMS License	Enterprise Edition Subscription-Sql/Oracle/or similar product	1	700,000	700,000	From database vendors
Operating System	Latest Windows professional Edition for desktops and laptops	6	11,000	66,000	From Software vendors
MS Office	Latest Edition required for desktops and laptops	6	9,000	54,000	From Software vendors
Total Cost of Software in Rs.				**820,000**	

Network and Communication: The integration of various systems and applications happens through the network and communication. Table 7-4 shows the details of estimated costs on network and communication components.

Table 7-4: Estimated Cost for Network and Communication

Component	Description	No. of Units Required	Cost per unit in Rs.	Cost in Rs.	Remarks
Modems, LAN Cables and other network accessories	CISCO or similar router with modem -Wi-Fi Enabled with 300 mbps connectivity	As required		50,000	Estimated
Telephone/IP Phone	From Either Tata/Airtel or similar	2	8,000	16,000	Estimated
Total Cost of Network and Communication in Rs.				**66,000**	

Services: There are certain services that are required for the functioning of the system:

i. **Enterprise Cloud for Database**: The database of CMC could be set up in a cloud. Several data centers are providing these cloud-based services. The cloud services will be taken from a III-tier data center. The minimum specifications of the cloud server would be 500 GB, 200 GB B/W, One IP address, 4 core 10 GB RAM, with backup space of 50 GB. The Madhya Pradesh State Data Centre (MPSDC), located in Bhopal, provides Tier-III equivalent services, which include servers, storage, connectivity, reliable hosting, backup and disaster recovery. Hence MPSDC can also be considered as an option while selecting the cloud-based database service provider. See **Annexure–III** for details on cloud computing.

ii. **OEM Antivirus**: Apart from necessary protection through the network firewall, each system should be protected through anti-virus software from vulnerabilities like malware, root kit, spam, phishing, Intrusion file detection, auto run protection, etc.

iii. **Domain and Hosting Charges**: The user interface of the CMC system is a web-enabled application. Hence it is necessary to have a permanent domain through which the users can access the CMC system.

iv. **Bandwidth Charges:** A minimum of 4 Mbps dedicated communication link should be enabled in MPUVNL.

Table 7-5: Estimated Cost for the Services

Services Component	Description	No. of Units Required	Cost per unit in Rs.	Cost in Rs.	Remarks
Virtual Server (Cloud-Based) with dedicated IP	First year recurring Charges on Virtual Server (Four core, 10 GB RAM, 500 GB HD, 200 GB bandwidth)	1	300,000	300,000	Details from database service provider
OEM Antivirus	Antivirus for 4 laptops and 2 PCs	6	1,200	7,200	Estimated
Domain and Hosting Charges	One Domain and necessary hosting			10,000	From domain service provider
Bandwidth Charges	4 Mbps dedicated line	4 Mbps	Rs. 50,000/Mbps	200,000	From Internet Service Provider
Total recurring cost for the first year in Rs.				**517,200**	

Implementation Charges: Experts from different fields are required for the implementation of the CMC system.

Table 7-6: Estimated Cost for Implementation

Expert	Description	No. of Man days Required	Cost per Man day in Rs.	Cost in Rs.	Remarks
Project Manager	With Minimum 15 years experience, in which at least for five projects he/she should have co-ordinated, planned and controlled projects through the Project Life Cycle - from Requirements study to commissioning and support	10	35,000	350,000	Estimation based on various proposals of IT firms
Team Leader	With Minimum 10years experience, in which at least for three projects he/she should have co-ordinated, planned and controlled projects through the Project Life Cycle from Requirements through to handover and support	12	20,000	240,000	

Expert	Description	No. of Man days Required	Cost per Man day in Rs.	Cost in Rs.	Remarks
Domain Consultant	As a part of technical resource pool, with minimum 5 to 6 years experience in power/renewable energy sector	10	15,000	150,000	
System Architecture	As a part of technical resource pool, with minimum 5 to 6 years experience in IT system architecture	15	10,000	150,000	
Network Expert	As a part of technical resource pool, with minimum 5 to 6 years experience in design, implementation and administration of network	25	7,000	175,000	
Database Programmer	As a part of technical resource pool, with minimum 3 to 5 years experience in handling different database implementation and integration	45	8,000	360,000	
Web Developer and System Design	As a part of technical resource pool, with minimum 2 to 4 years experience in design of web-based online user interface	45	6,000	270,000	
Overhead charges (20%)				**339,000**	
Training, Documentation of User Manual				200,000	
Total Cost of Implementation in Rs.				**2,234,000**	

The total estimation of the funding requirement including all the components required for the development phase of the CMC system is shown in Table 7-7.

Table 7-7: Development Cost Estimate of CMC system

Component Heads	Cost in Rs.
Hardware	710,000
Infrastructure	270,000
Software	820,000
Network and Communication	66,000
Implementation Charges	2,234,000
Recurring Cost for services in First Year	517,200
Total One-time development cost for CMC Implementation	**4,617,200**

The development cost for the CMC system has been estimated at **Rs 46.17 lakh plus applicable taxes.** This cost includes the cost required for hardware, infrastructure, software and implementation. The development of the CMC system would be awarded to the CMC IT system developer on turnkey basis.

7.2 CMC SYSTEM OPERATION PHASE

There are certain services that are needed throughout the lifecycle of the CMC operation. The costs during the operating phase comprise the recurring costs for the server, applications, license fees (as applicable), communication and bandwidth costs, annual maintenance contract charges, etc. Based on this, the estimated recurring cost to operate and maintain the CMC system is shown in Table 7-8.

To operate and maintain the CMC system, it is estimated that around **Rs 8.17 lakh/annum plus applicable taxes** would be required for MPUVNL. No manpower cost for MPUVNL has been budgeted, as it is assumed that existing manpower with MPUVNL will be adequate to monitor the CMC system during the operating phase.

It is recommended that for the initial period, at least for a period of three years, the CMC system developer should take care of the operation and maintenance of the CMC system.

Table 7-8- Recurring Cost of CMC System

Recurring Cost Component	Description	No of Units Required	Cost per unit in Rs.	Cost in Rs.
Virtual Server (Cloud-Based) with dedicated IP	Virtual Server (Dual Core 2 GHz, 8 GB RAM, 1 TB HD with SATA with Backup Agent)	1	300,000	300,000
Bandwidth Charges	(4 Mbps Dedicated Line)	4 Mbps	Rs 50,000/Mbps	200,000
Domain and Hosting Charges	1 domain name and hosting charges	-	-	10,000
Annual Maintenance Charges from CMC System Developer	For Remote support of the system			300,000
OEM Antivirus	First year Recurring Charges	6	1,200	7,200
Total Recurring Cost from second year onwards (Rs)				**817,200**

7.3 DEVELOPMENT OF CMC SYSTEM BY IT DEVELOPER

The development of the CMC system would be awarded on a turnkey basis to the CMC IT system developer. The steps involved in the development of the CMC system by the developer are:

- Step 1: Development of system requirements document, which includes system algorithm and architecture and getting necessary approval from MPUVNL for the go-ahead for development
- Step 2: Procurement of software
- Step 3: Development of application through programming
- Step 4: Procurement of necessary hardware
- Step 5: Arrangement of necessary services and infrastructure facilities
- Step 6: Application runs on test bed and getting acceptance from MPUVNL
- Step 7: Deployment of complete solution
- Step 8: Monitoring of the system for satisfactory performance
- Step 9: Documentation of user manual for the CMC system
- Step 10: Providing training to the MPUVNL staff and operators
- Step 11: End of development phase and starting of maintenance phase

8 ROADMAP AND TIMELINE FOR CMC IMPLEMENTATION

The course of action in the development of CMC would be in four stages: Stage 1: Conceptualization Stage, 2: Pre-Development Stage, 3: Development Stage, and 4: Post-Development.

Conceptualization Stage: The mission of this stage is to have a clear picture about the requirements of CMC, its functionalities, and the budgetary cost estimation for the development of the CMC system. There are three major activities involved in this stage:

1. The study of on existing off-grid system and its monitoring methodology used by MPUVNL. Evaluation of options to implement the CMC (PACE-D TA Program)
2. Preparation of Detailed Project Report for the proposed CMC system.
3. Arrangement of funds for the CMC system. (MPUVNL)

Pre-Development Stage: In this stage, the mission is to find a suitable CMC system developer. Both MPUVNL and PACE-D TA Program are involved in: Preparation of tender document and Request for Proposal

1. Pre-Bid meeting with the bidders
2. Evaluation of proposal submitted by bidders
3. Selection of CMC system developer and signing a contract with them

MPUVNL would consolidate the details of off-grid systems to be monitored by the CMC system and seek commitment from the corresponding off-grid vendors on the automated data sending mechanism.

Development Stage: In this stage, the CMC will be developed and deployed. The activities involved are:

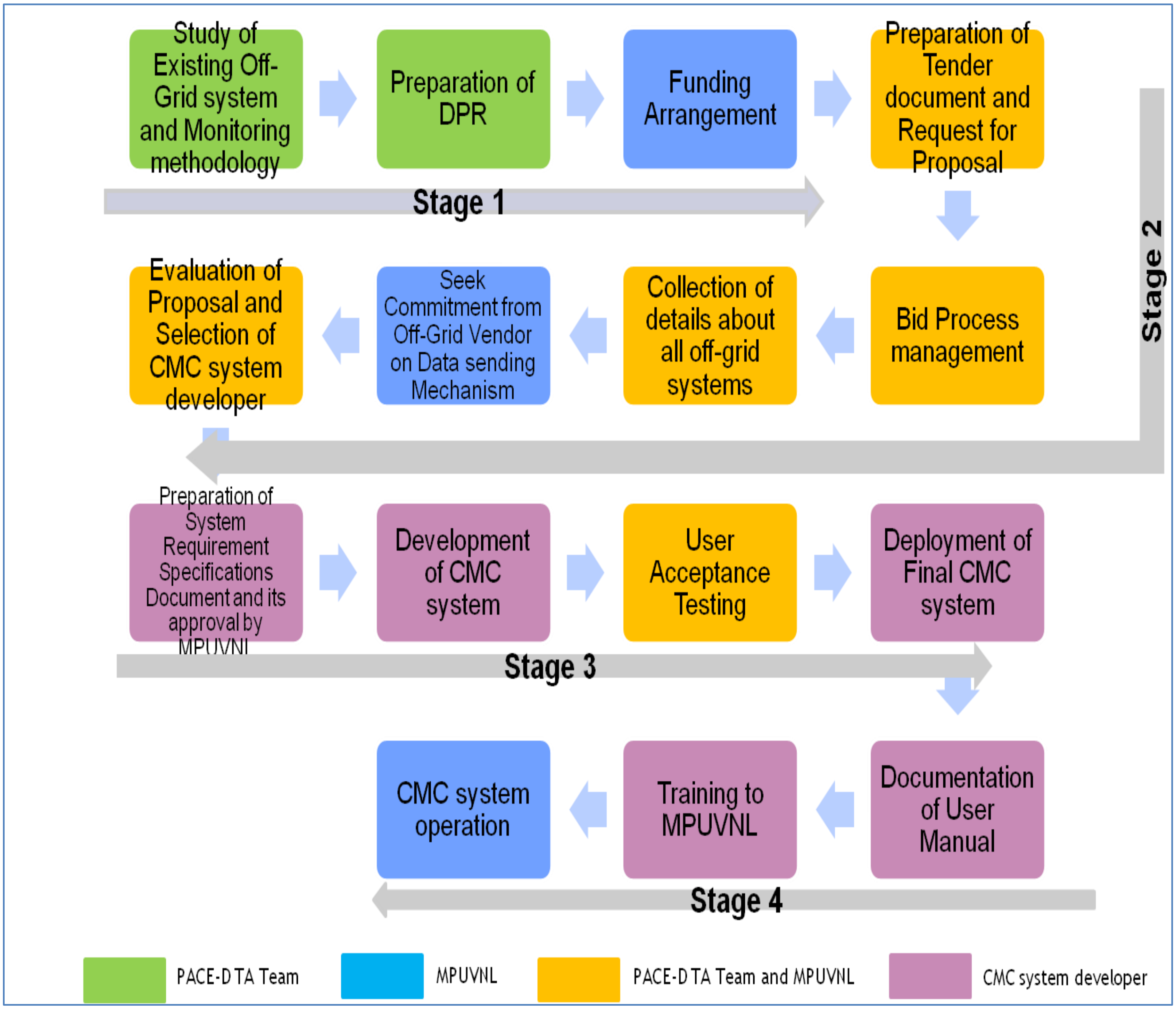
1. Preparation of system requirement specification by CMC IT system developer and approval from MPUVNL
2. Development of CMC system (by CMC IT System developer)
3. User acceptance testing (by MPUVNL and PACE-D TA Program)
4. Deployment of final CMC system (by CMC IT System Developer)

Post- Development Stage: In this stage, the CMC system will be functional. The activities involved are:

1. CMC system developer would prepare the user manual for CMC system
2. Training to MPUVNL staff on the functioning of CMC system
3. MPUVNL takes control of CMC operation

The roadmap of the CMC system development is shown in Figure 8-1.

Figure 8-1: Roadmap of CMC System Development



Timeline: It is envisaged that the total time required from the concept stage to the operation of the CMC system would be 11 months. However, it may be appreciated that the adherence to the timeline would significantly depend upon the timely completion of the tender process and putting in place approvals in a timely manner. The activity-wise timeline for the project is as shown in Table 8-1.

Table 8-1: Timeline of CMC System Development

S.NO	Activity	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11
Stage 1	**Conceptualization Stage**											
1	Study on Existing off-grid system and monitoring methodology	■										
2	Preparation of DPR		■	■								
3	Funding Arrangement				■							
Stage 2	**Pre-Development Stage**											
4	Preparation of Tender and Request for Proposal					■						
5	Bid Process management					■	■					
6	Collection of details of off-grid system to be monitored					■						
7	Seek commitment from off-grid vendor on data sending mechanism						■					
8	Evaluation of Proposal and selection of CMC system developer							■				
Stage 3	**Development Stage**											
9	Preparation of System requirement specification and approval by MPUVNL								■			
10	Development of CMC system								■	■		
11	User Acceptance Testing									■		
12	Deployment of Final CMC system										■	
Stage 4	**Post-Development Stage**											
13	Documentation of user manual										■	
14	Training to MPUVNL											■
15	CMC System operation											■

9 CONCLUSION

The off-grid vendor-based centralized monitoring system would be the effective solution for the development of the CMC system at MPVUNL to monitor off-grid SPV systems in the state. The success of this system solely depends on the acceptance of the automated data sending mechanism by the off-grid vendors. Hence, MPUVNL needs to seek firm commitment from off-grid vendors to provide requisite data in an automated way, at regular intervals of one hour to the CMC system, with 15/30/60 minutes (as feasible) data granularity. The CMC IT system developer would develop the CMC system based on the off-grid vendor-based centralized monitoring system model.

Funds need to be arranged for the establishment of the CMC system. The CMC system to presently monitor the off-grid SPV systems can, in future, be used to monitor other off-grid system applications such as bio-gasifiers, solar water heating installations, solar pump installations, etc. Currently, the subsidy disbursement by the central and state governments is not linked to the performance of off-grid SPV systems. The data analysis by the CMC system can be used to link subsidy with performance of the system.

The proposed off-grid CMC system is the first of its kind in India. Upon successful implementation of this system by MPUVNL, the same model or the off-grid facility-level meter integrated centralized monitoring system can be implemented by other state nodal agencies in the country to monitor the off-grid systems.

For future upcoming programs, MNRE/state nodal agencies may consider including a similar kind of performance monitoring system and linking the subsidy disbursement with the performance. This would enhance the utility of the program for the beneficiaries and help them in improving monitoring the outcomes of the program in an effective manner.

10 ANNEXES

ANNEXURE I- DETAILS OF FINANCIAL ASSISTANCE TO OFF-GRID SYSTEMS IN MP

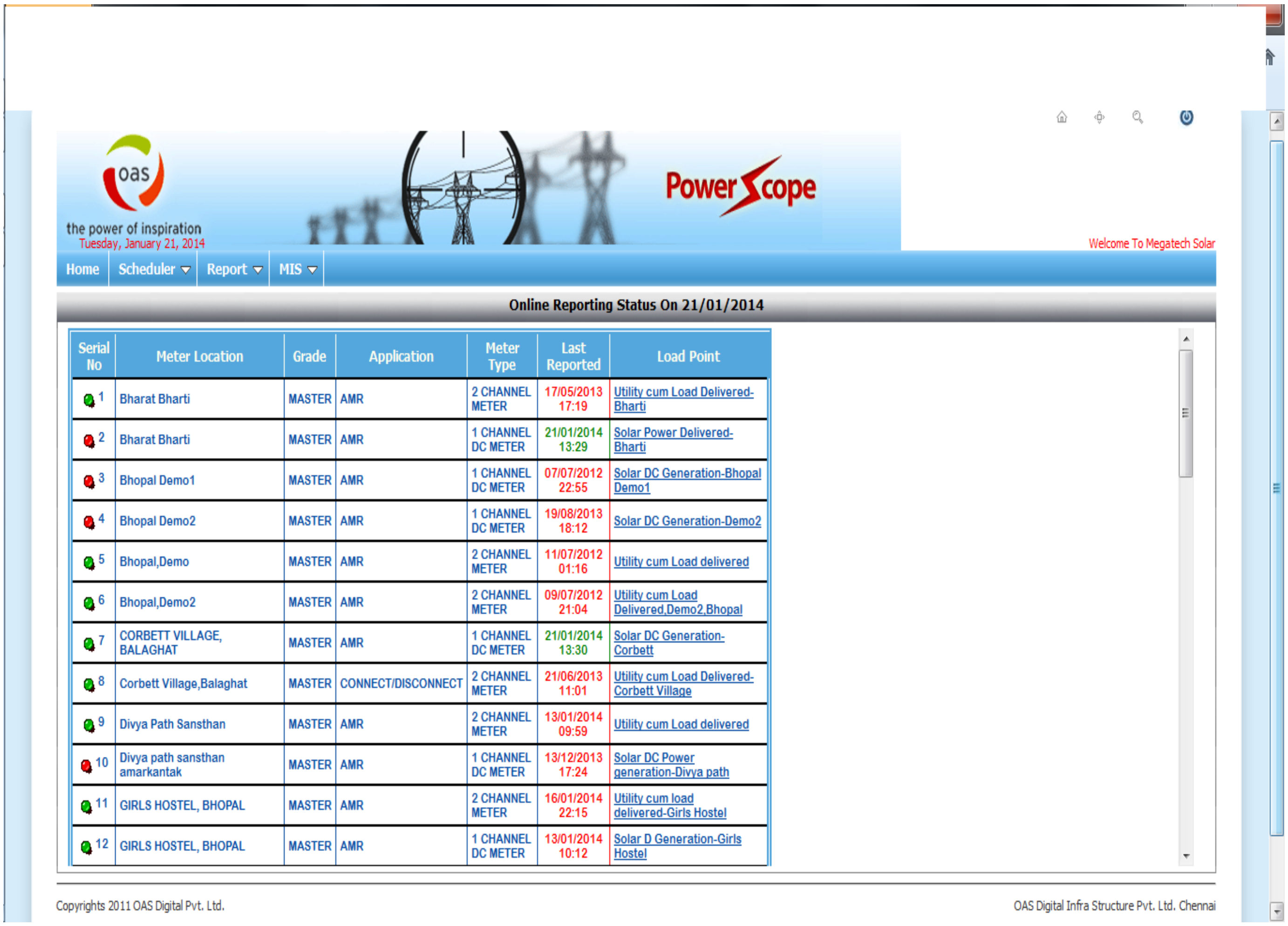
Table 10-1-Details of Financial Assistance to Off-Grid Systems in MP

Category of Beneficiary	Capacity Range	Govt. of India's Assistance (Approx)	Govt. of MP's Special Assistance (Approx)	Total Financial Assistance
Govt./Semi Govt.	All capacities	@ 30% of the cost of the project	@ 20% of the cost of the project	Approx. 50% of the cost of the project
Private Institutional	Only 5 kW and up to 25 kW capacity	@ 30% of the cost of the project	@ 20% cost of the cost of the project	Approx. 50% of the cost of the project
Private Individual	All capacities	@ 30% of the cost of the project	--------	Approx. 30% of the cost of the project

ANNEXURE II- USER INTERFACE OF DIFFERENT OFF GRID VENDORS

The following is the screenshot of the user interface belonging to the off-grid vendor Meghatech. Currently this vendor has installed more off-grid systems than other off-grid vendors.

Figure 10-1- Home page of Off-grid vendor User Interface (Meghatech)



Serial No	Meter Location	Grade	Application	Meter Type	Last Reported	Load Point
1	Bharat Bharti	MASTER	AMR	2 CHANNEL METER	17/05/2013 17:19	Utility cum Load Delivered-Bharti
2	Bharat Bharti	MASTER	AMR	1 CHANNEL DC METER	21/01/2014 13:29	Solar Power Delivered-Bharti
3	Bhopal Demo1	MASTER	AMR	1 CHANNEL DC METER	07/07/2012 22:55	Solar DC Generation-Bhopal Demo1
4	Bhopal Demo2	MASTER	AMR	1 CHANNEL DC METER	19/08/2013 18:12	Solar DC Generation-Demo2
5	Bhopal,Demo	MASTER	AMR	2 CHANNEL METER	11/07/2012 01:16	Utility cum Load delivered
6	Bhopal,Demo2	MASTER	AMR	2 CHANNEL METER	09/07/2012 21:04	Utility cum Load Delivered,Demo2,Bhopal
7	CORBETT VILLAGE, BALAGHAT	MASTER	AMR	1 CHANNEL DC METER	21/01/2014 13:30	Solar DC Generation-Corbett
8	Corbett Village,Balaghat	MASTER	CONNECT/DISCONNECT	2 CHANNEL METER	21/06/2013 11:01	Utility cum Load Delivered-Corbett Village
9	Divya Path Sansthan	MASTER	AMR	2 CHANNEL METER	13/01/2014 09:59	Utility cum Load delivered
10	Divya path sansthan amarkantak	MASTER	AMR	1 CHANNEL DC METER	13/12/2013 17:24	Solar DC Power generation-Divya path
11	GIRLS HOSTEL, BHOPAL	MASTER	AMR	2 CHANNEL METER	16/01/2014 22:15	Utility cum load delivered-Girls Hostel
12	GIRLS HOSTEL, BHOPAL	MASTER	AMR	1 CHANNEL DC METER	13/01/2014 10:12	Solar D Generation-Girls Hostel

This system lists out the off-grid system belongs to the off-grid vendor A. It gives the system status also.

Figure 10-2- System Status Page of Off-grid Vendor User Interface (Meghatech)

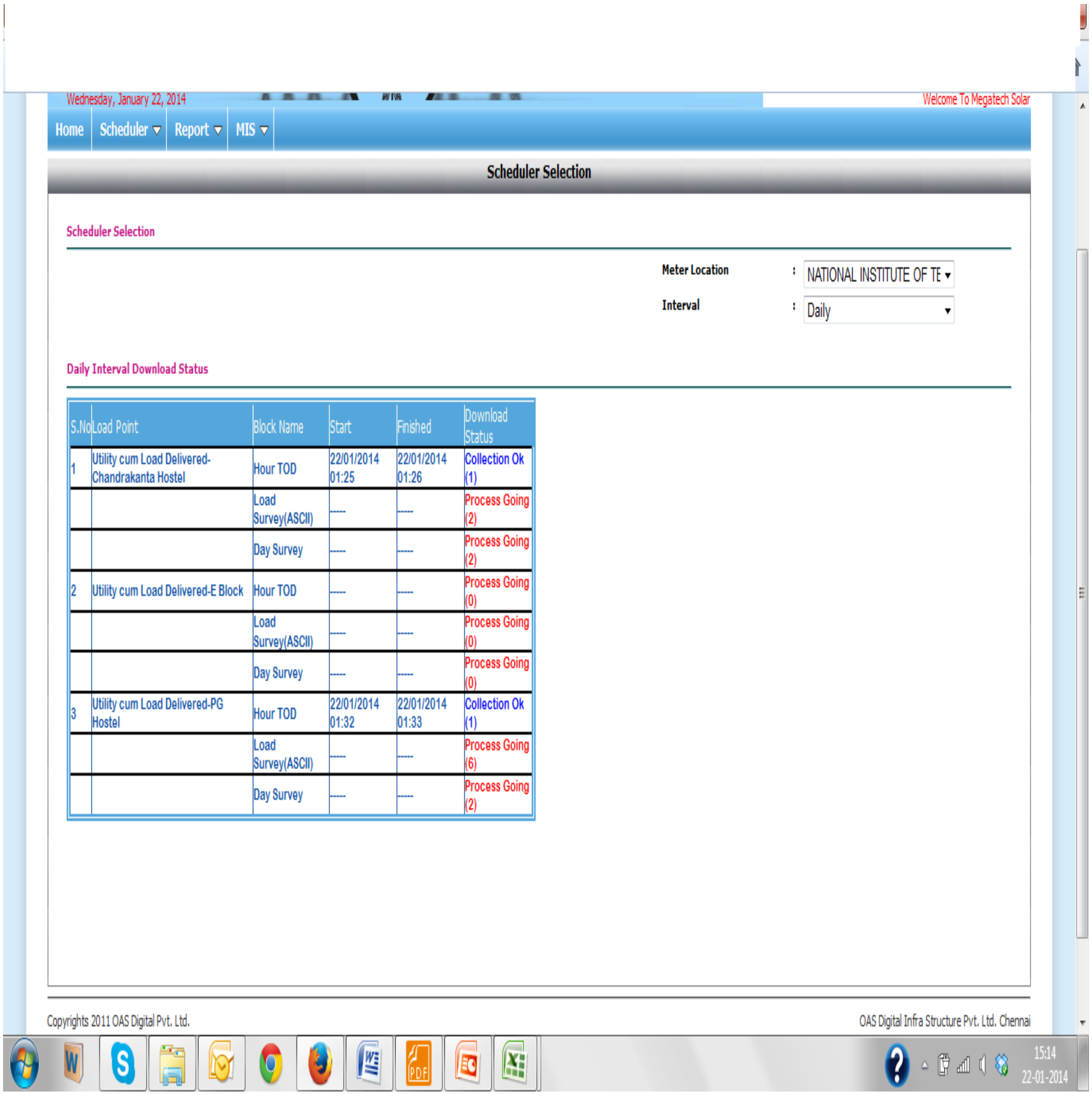


Figure 10-3-Executive Summary of Off-grid Vendor User Interface (Meghatech)

Figure 10-4- Home Page of Off-grid Vendor User Interface (Indo Solar)

UPS	Details	Date	Time	Solar Inv.Details	Location	Solar KVA	Solar KVAH	Status	Type
3PhUps50025	Three PH	19-Nov-2013	07:14 PM	25 KVA	1250 JP Hospital, Bhopal	3	93.5	Disconnected	Old3P
3PhUps70353	Three PH	19-Nov-2013	07:08 PM	15 KVA	Civil Hospital,Bairagarh,Bhopal	0	65.4	Awating Update	Old3P
3PhUps46381	Three PH	12-Nov-2013	10:28 AM	25KVA	Income Tax Office , Ujjain	3	93.5	Awating Update	Old3P
3PhUps52934	Three PH	09-Nov-2013	08:34 AM	15 KVA	Rajiv Gandhi Hospital, Ganj Basoda,Bhopal	0.3	46.3	Awating Update	Old3P
3PhUps50108	Three PH	10-Oct-2013	12:00 PM	20 KVA	Civil Hospital,Raisen,Bhopal	10.7	50.7	Awating Update	Old3P

Figure 10-5- Status Page of Off-grid Vendor User Interface (Indo Solar)

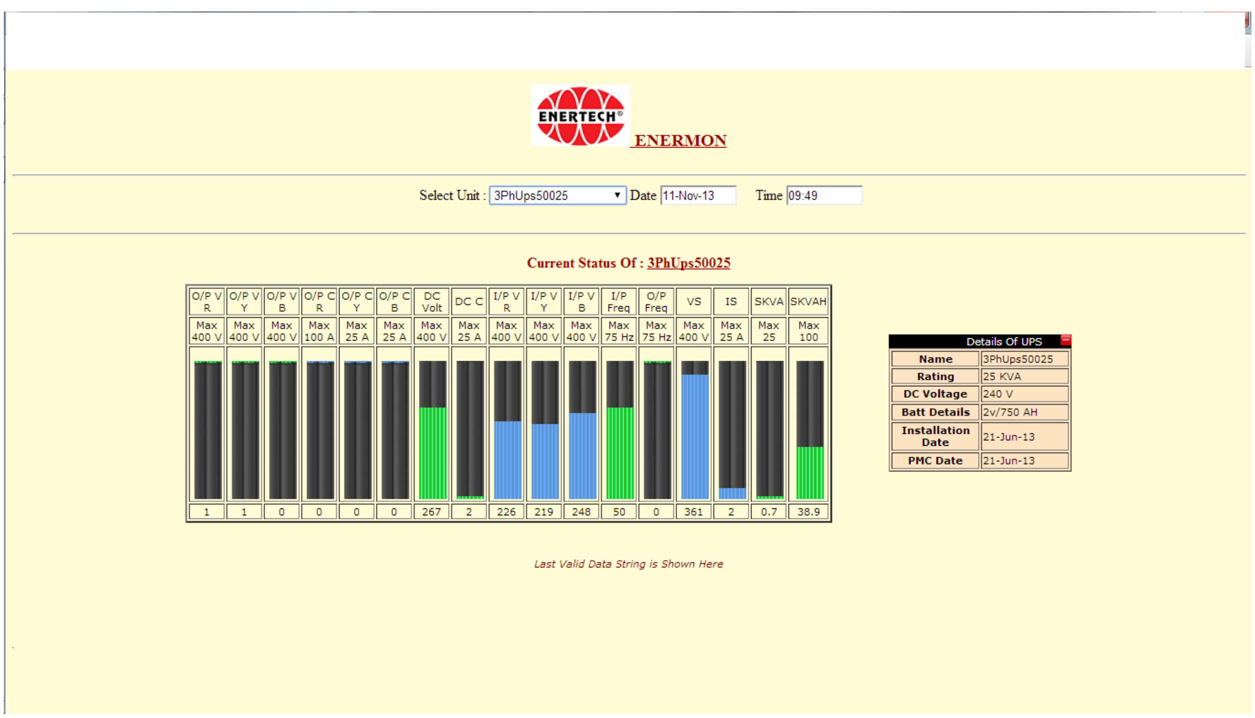
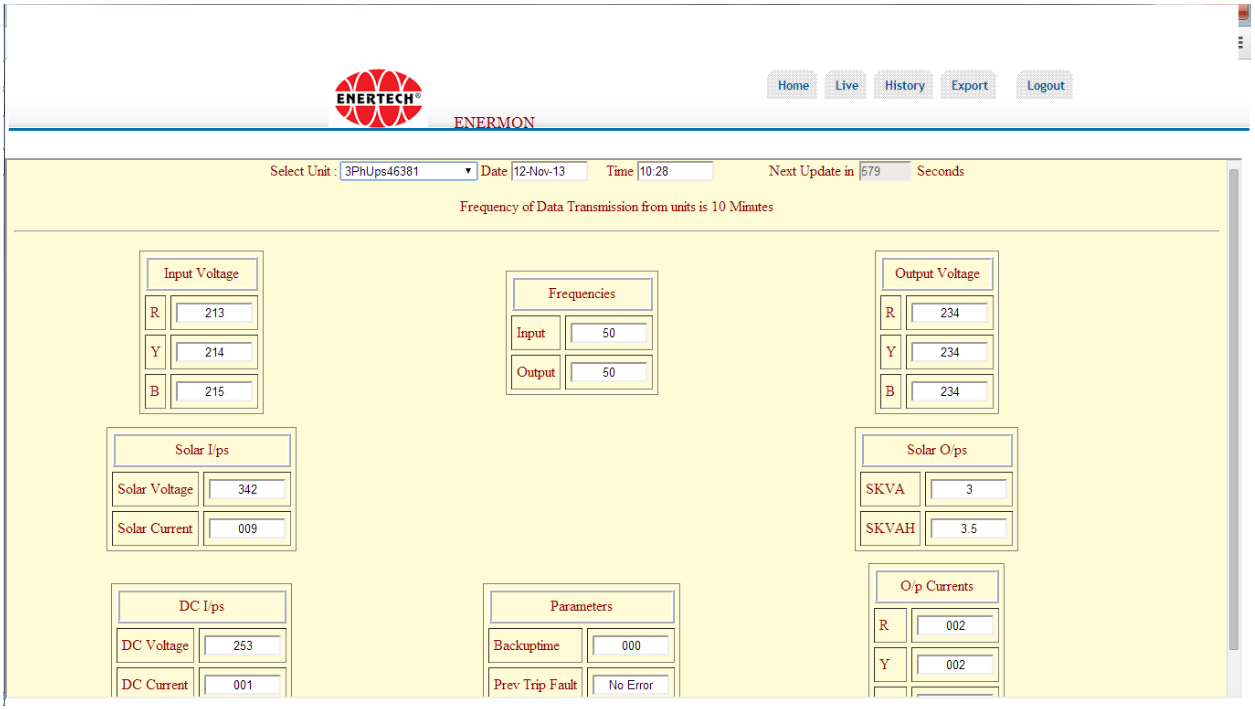


Figure 10-6- Live Status of Off-Grid Vendor User Interface (Indo Solar)



ANNEXURE III – DETAILS ON CLOUD COMPUTING

Cloud computing is a network of a large number of computers connected through a real-time communication network such as the Internet. Cloud computing is also known as distributed computing over a network, and means the ability to run a program or application on many connected computers at the same time. The phrase also more commonly refers to network-based services, which appear to be provided by real server hardware, and are in fact served up by virtual hardware, simulated by software running on one or more real machines. Such virtual servers do not physically exist and can therefore be moved around and scaled up or down without affecting the end-user or the application.

Cloud computing relies on sharing of resources to achieve coherence and economies of scale. It is the broader concept of converged infrastructure and shared services. The Cloud also focuses on maximizing the effectiveness of the shared resources. Cloud resources are usually not only shared by multiple users but are also dynamically reallocated per demand. This can work for allocating resources to users.

Cloud computing can be divided into three distinct classes of services.

1. Software-as-a-Service (SaaS)
2. Platform-as-a-Service (PaaS)
3. Infrastructure-as-a-Service (IaaS)

Software-as-a-Service (SaaS) - Let's start at the highest level: software applications that are only available online fall into the "Software-as-a-Service" category, also known as "SaaS". The simplest example to understand is e-mail.

If you have an Internet provider, you'll need a desktop or mobile application to access that e-mail, else host it on your own servers. Not only would you have to run an inbound mail server using protocols such as Internet Message Access Protocol (IMAP); or Post Office Protocol (POP) for older systems, but you would also need to run an SMTP or outbound mail server. Then you'd have to configure your desktop or mobile e-mail application to connect to those servers, add appropriate levels of security, quota management, etc.

For personal e-mail, people typically select from a variety of free web-based e-mail servers such as Google's Gmail, Yahoo Mail, or Microsoft's Hotmail, rather than setting up all of the above through their provider. Not only is it "free" (supported through advertising), but users are freed from any additional server maintenance. Another example of SaaS from Google includes their Apps product: office productivity software hosted and run by Google online.

Because these applications run (and store their data) online, users no longer need to worry about managing, saving, and backing up their files. Of course, now it becomes Google's

responsibility to ensure that your data is safe and secure. Other examples of SaaS include Sales force, IBM's Net Suite, and online games.
The easiest way to think of SaaS is like this: It is software, but do you download and install it on your computer, or do you access it using a web browser or mobile app? If the latter, you've likely got a SaaS Cloud application on your hands. Note that you don't have control of these applications, short of user-specific application settings. You can't fix bugs in the code or make changes to it. This is the responsibility of the vendor. To some, this lack of control is unacceptable.

Infrastructure-as-a-Service: Infrastructure-as-a-Service is where you outsource the hardware. In such cases, it's not just the computing power that you rent; it also includes power, cooling, and networking. Furthermore, it's more than likely that you'll need storage as well. Generally IaaS is this combination of compute and Cloud storage.

When you choose to run your applications at this Cloud service level, you're responsible for everything on the stack that is required to operate above it. By this, we mean necessities such as the operating system, followed by additional (yet optional services) like database servers, web servers, load-balancing, monitoring, reporting, logging, middleware, etc. Furthermore, you're responsible for all hardware and software upgrades, patches, security fixes, and licensing, any of which can affect your application's software stack in a major way.

Platform-as-a-Service: At the Platform-as-a-Service service level, the vendor takes care of the underlying infrastructure for you, giving you only a platform with which to (build and) host your application(s).

Systems like Google App Engine, Salesforce's Heroku and force.com, Microsoft Azure, and VMwares Cloud Foundry, all fall under the PaaS umbrella. Not only do these systems provision the hardware for you, but generally, you don't have to worry about those other necessary infrastructure components such as software upgrades, patches, and licensing. Interestingly, when you use *PaaS* platforms, the types of apps you create with them are *SaaS* applications.
Refer **Error! Reference source not found.** for cost comparison between In-house servers and Cloud-based servers.

Table 10-2- Cost Comparison between In-House vs Cloud Server

Item	In-House (Rs)	Cloud Based (Rs)	Explanation
Up-Front Costs			
Server Hardware	Rs. 130,000		Dual Core, 8 GB RAM, 1 TB HDD, 2 GHz
Server Software (OS)	Rs. 50,000		
Ancillary Server Equipment	Rs. 10,000		UPS, Switch, Rack, etc
Installation Cost	Rs. 5,000		
Total Upfront Costs (A)	**Rs. 195,000**		
Estimated Useful Life (Months)	36		Typical lifetime of Server
Monthly Costs			
Maintenance and Monitoring	Rs. 10,000		
Offsite/Online Backup Costs	Rs. -	-Included-	
Cloud Hosting Costs	Rs. -	Rs 25,000	8 GB RAM, 1 TB HDD, 200 GB Bandwidth, Windows 2008 OS
Bandwidth Charges	Rs. 17,000	Included-	To have a reliable bandwidth to access the in-house server
Electricity Charges	Rs. 6,000		Electricity consumption by the server and air conditioner
Total Monthly Costs	**Rs. 33,000**	**Rs. 25,000**	
Total Monthly Costs for 36 Months (B)	**Rs. 1,188,000**	**Rs. 900,000**	
Unplanned Repair Cost (-C-)	**Rs. 50,000**	**-**	Over the period of lifetime of In-House server
Total Cost in the life time (A+B+C)	**Rs. 1,433,000**	**Rs. 900,000**	Total Cost over estimated life/Analysis period

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