POWER ANALYSIS TOOL

Estimates Power, Performance, Form-Factor and Battery life

Submitted By

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AHMEDABAD-382481

March 2016

POWER ANALYSIS TOOL

Major Project

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Computer Science & Engineering

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Certificate

This is to certify that the Project entitled "Power Analysis Tool" submitted by Patel Jignesh N. (14MCEC19), towards the partial fulfillment of the requirements for the degree of Master of Technology in Computer Science & Engineering of Nirma University, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this Project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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This is to certify that Mr. Jignesh N. Patel (14MCEC19), a student of M. Tech. CSE, Institute of Technology, Nirma University is working with us since 17th June, 2015 and carried out his thesis work titled "Power Analysis Tool". He is working as a Software Development Intern under the supervision of Mr. A, Chockalingum (Mentor) and Mr. Satish Prathaban(Manager). He has successfully completed the assigned work and is allowed to submit his dissertation report. We wish him all the success in future.

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Statement of Originality

I, **Jignesh N. Patel**, **14MCEC19**, give undertaking that the Major Project entitled "**Power Analysis Tool**" submitted by me, towards the partial fulfillment of the requirements for the degree of Master of Technology in **Computer Science & Engineering** of Institute of Technology, Nirma University, Ahmedabad, contains no material that has been awarded for any degree or diploma in any university or school in any territory to the best of my knowledge. It is the original work carried out by me and I give assurance that no attempt of plagiarism has been made.It contains no material that is previously published or written, except where reference has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Acknowledgements

I would like to take this opportunity to thank the people who helped me in my project work. First of all, I would like to thank A, Chockalingam, for being my mentor and guiding me in every step of project, Prof. Dr. Ankit Thakkar for giving me an opportunity to work under his guidance. I would like to thank Satish Prathaban (Manager, Power Delivery Team) for his valuable guidance and support. I would also like to thank G, Naveen from bottom of my heart for detail explanation of project requirements and power concepts. This list is incomplete without my friends and Power Delivery (PD) Team members who helped me out whenever required. At last I am thanking Nirma University and Intel Corporation for providing resources and suitable environment for research.

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Abstract

Power management is one of the critical task while designing electronic devices. Electronic devices are made up of many components and each component has its own resource requirements. It is very complex and time consuming task for human to analyze power and cooling requirements of components, calculate whole system power and cooling needs and design optimal system within given cost limit. Power analysis Tool is single point control that can be used to simulate system for power and performance needs. It takes system details and expected benchmark scores as an input and gives detail power, thermal and form-factor analysis of target system. These Analysis results will be used in architecture, designing and validation phase.

Abbreviations

- **PAT:** Power Analysis Tool
- **PD:** Power Delivery(PD) is team of Intel India.
- **BOM:** Bill Of Materials
- **SKU:** Stock Keeping Units(SKU) are different variants of processors (say i5 xyz, i7 abc etc)
- **KPI:** Key Performance Indicator
- **TDP:** Thermal Design Power is used to design cooling solution to dissipate the heat generated in system.
- **ICC:** Maximum current requirement of the platform.
- **NTLM:** NT LAN Manager (NTLM) is a suite of Microsoft security protocols that provides authentication, integrity, and confidentiality to users.
- **JSON:** JavaScript Object Notation
- **DOM:** The Document Object Model(DOM) is an official recommendation of the World Wide Web Consortium (W3C). It defines an interface that enables programs to access and update the style, structure,and contents of XML documents.
- **SAX:** Simple API for XML is an event-driven algorithm for parsing XML documents, with an API interface developed by the XML-DEV mailing list. SAX provides a mechanism for reading data from an XML document that is an alternative to that provided by the Document Object Model (DOM).

- **SAR:**Specific Absorption Rate is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field.

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Chapter 1

Introduction

1.1 Overview

Electronic devices are made up of different components having different cost, various resource requirements and performance limit. Designing a product which satisfies user's performance requirements and having best cost is very challenging and time consuming task. Best solution is to analyze capability of all available components with respect to performance and determine the best option for each part but this manual work is too complex and time consuming. To avoid such complexity and make process smoother and efficient, we need system which collects system configuration and performance requirements from user, simulates these requirements and gives detail architectural analysis report of target system. There is no existing tool available which predicts power,thermal, battery life and form factor analysis from expected system configuration and workload score and gives deep analysis report.

Power Analysis Tool is a web based simulator, designed to assist in product architecture and design phase. Tool communicates with global catalog to recommend optimal system configuration and SKU. As an input, Tool takes list of components, values for system properties and performance parameters. Input page is divided into

3 sections

- **System Components:** This section collects system configuration requirements from user. It fetches component list from global catalog database and show them in Mandatory and Optional group. Mandatory components are these components which are compulsory for proper operation of system while Optional components provide additional functionalities like connectivity, sensing etc. By default, optimal choice is selected for each component.

- **System Properties:** System Properties are divided into SAR, Display and Thickness category. Properties like Antenna distance from Surface, Display Type,Bonding Methods,Touch type,Component Heights etc are come in this section

- **System Performance:** This section takes performance requirements of each benchmark in form of score. Workloads are grouped by their types for example 3DMark is graphics benchmark so it reside in Graphics section while 3DMark-FireStrike benchmark resides in Gaming section.

These requirements are verified at client side and passed to server. Server runs simulator instance with these inputs and return result in 3 parts

- **Cost:** Gives overall cost of system. Individual cost of components are added and gives the overall cost of System. System Cost enables user to choose SKU's components within given cost limit.

- **System Feature:**Result of SAR, Display,Battery and Thickness information come here.

- **Power & Thermal Analysis:** This section gives the best TDP-ICC combination that satisfies performance requirements of each workload, suggests best Power Configuration and cooling need, Recommended devices and Area details of target system. Tool also draw block diagram of PowerMap that shows power distribution across system.

Before Tool loads, it checks user permissions by getting user windows login details and comparing it with Tool's User database. User can explore tool if and only if he has enough permissions. If user doesn't have enough permission then he has to request it. When tool loads, It fetches mandatory details like components and Sub components details from Global Component DB, Workloads and System Properties information from local Database. Once all data come, it enables user to specify his requirements by selecting part number for each component,score for each benchmark and value for each system property. All these requirements are pass to server for simulation and simulation results are send back to client machine. Results are organized into multiple sections in output window. In output window, User can play with different settings parameters and analyse the performance variation.
Tool maintains profile for each user in which he can store all his work information and configuration settings. Profile module allows user to save the settings in public and private mode and later load it in tool. Private settings are only visible to owner, while public settings are visible to all privileged user. User can search saved settings and load it in tool.This functionality allows user to start work from last restore point. Profile module also allows to save and load settings in offline mode.

1.2 Objectives

Product is designed to achieve below objectives

- Integrated Windows Authentication to identify user's role and authorities. Only Privileged user can access the tool. User has to request for access if he doesn't have permission.
- Communicate with global catalog DB for fetching latest component and sub-components details.
- Ability to view TDP/ ICC max per workload/ comparative analysis for different TDP/ ICC in tabular format.

- Provide various graphs for further power analysis. Graphs can point to specific SKU points and have zoom in/ out functionality.
- HTML UI for regular/ admin user + database backend that is scalable.
- Treat each SKU independently. Simulation result must be vary base on SKU configuration.
- Efficient Prediction algorithm to predict missing values of SKU dataset.
- Design and logic of system should be scalable. SKU dataset must be decided during runtime.
- Enable a customer to pick a SKU based on the following Inputs:
  - Benchmark Performance number and Power Limits
  - Form Factor
  - System Components
  - System Properties
  - Bill of Material Cost
- The tool will recommend an optimal SKU/configuration that meets requirements and present Output in form of:
  - Cooling Power requirements
  - Actual Power Supplied
  - Voltage regulator Area
  - Height
  - Power Regulator BOM Cost
  - Form Factor recommended
  - Voltage Regulator(VR) Power Map Diagram for each form factor

  - Thickness and Area information
  - Battery Life

- Easier process for selection of SKUs (including System Configuration and Performance requirement) for different design wins
- Enables user to save current configurations and output in cloud in public and private mode and can retrieve it later.
- Sharing Module to share saved output with other users.
- Ability to add new platform components,KPI, System Properties and User for Super Privileged user.
- Easy management of SKU Dataset.

1.3 Purposes

Major purpose of the Tool is to assist in product architecture and product design phase. Main Purposes of tool are:

- Design simulator that accepts benchmark's score and SKU configuration and gives overall power analysis of system including Thermal analysis, Form-factor information, Battery and Power distribution Map
- Provide one click SKUs analysis and recommends best configuration with its possible values for each property.
- Results should be displayed in various graphs and tabular form which helps in comparative analysis of different configurations.
- VR PowerMap shows overall power distribution across the system which gives base to designer to design system power diagram.

- Profile management module for storing, retrieving and sharing user's configuration settings and role..
- Store and process large amount of SKU data with minimum time and Space complexity.

Chapter 2

Requirement Analysis

Requirement analysis explore project to find out potential resource requirements during development and deployment phase. Here I am listing out resources that are used during development phase.

2.1 Hardware Requirements

- Processor: Intel(R) Core(TM) i5 3rd Generation
- Hard disk Space: 30 GB
- RAM: 4 GB DDR3

2.2 Software Requirements

- OS: Windows 7 or above
- Platform: .Net
- Technology: ASP.Net + AngularJS
- Language: C sharp

- Backend: SQL server 2008
- IDE: Visual Studio 2013
- API used: JQuery, Canvas Chart

2.3 Security Requirements

- Only granted user can access tool. If he does not have permission, user has to get permission to access the tool.
- User can only authenticate himself using windows NTLM authentication protocol.
- Only Super Privileged user can perform site management activities.

2.4 Data requirements

Tool uses below files to predict Performance, Power and Thermal parameters.

- **SKU File**

  This file very significant for tool, tool is useless without this data. It is excel file that contains simulated result of benchmark score at various System Configuration, TDP and ICC values. Super Privileged user uses this file to initialize SKU, Workload and TDP-ICC database. To predict optimal solution, simulator filter out best TDP ICC pair from file that matches system performance requirement and suggests best available configuration from possible configurations.

- **System Component**

  This contains list of components and its sub components with their cost and power requirements. Tool fetches these items and prompts user to create his target System Configuration by picking a optimal choice for each component.

- **Area Information File**

  This is supporting information with SKU data. It contains TDP-ICC pair cost, thickness and recommended devices information. Matching TDP-ICC pair got from TDP-ICC calculation are compared with this file to get approximate cost,thickness and recommended device information.

- **Power Rail Information**

  This file contains power and thermal details of each subcomponents. Rail information of each selected sub component is use to design PowerMap diagram(Distribution of power across platform).

Chapter 3

Type of Users

Product will be accessed in restricted environment of Intel, so only verified user can access it. Tool verifies user using NTLM authentication protocol and determine user's role. Each role has given set of authorities. There are 2 types of users

- **Privileged User**
  - They use the system for product architecture and design assistant purpose.
  - They specify their requirements in form of expected score for each benchmark, System properties and target system configuration, to get overall power and Thermal analysis report as an output.
  - Tool allows to save input settings into the cloud/file and it can be accessed later. User can also search and access shared settings of other users.
- **Super Privileged User**

  Super Privileged users are responsible for
  - Managing User Access Request.
  - Maintaining SKU, Workload and TDP-ICC database via SKU file
  - Managing System Configuration and Properties information
  - Maintaining Rail and Area Database via Rail and Area file.

Chapter 4

Implementation Details

This section described how different modules work with each other to generate desired results.

4.1 System Design

Product is divided into 3 major modules.

- Client Module (UI Module)
- Server Module
- Database Handler

Each module consists of multiple sub-modules which are explained below.

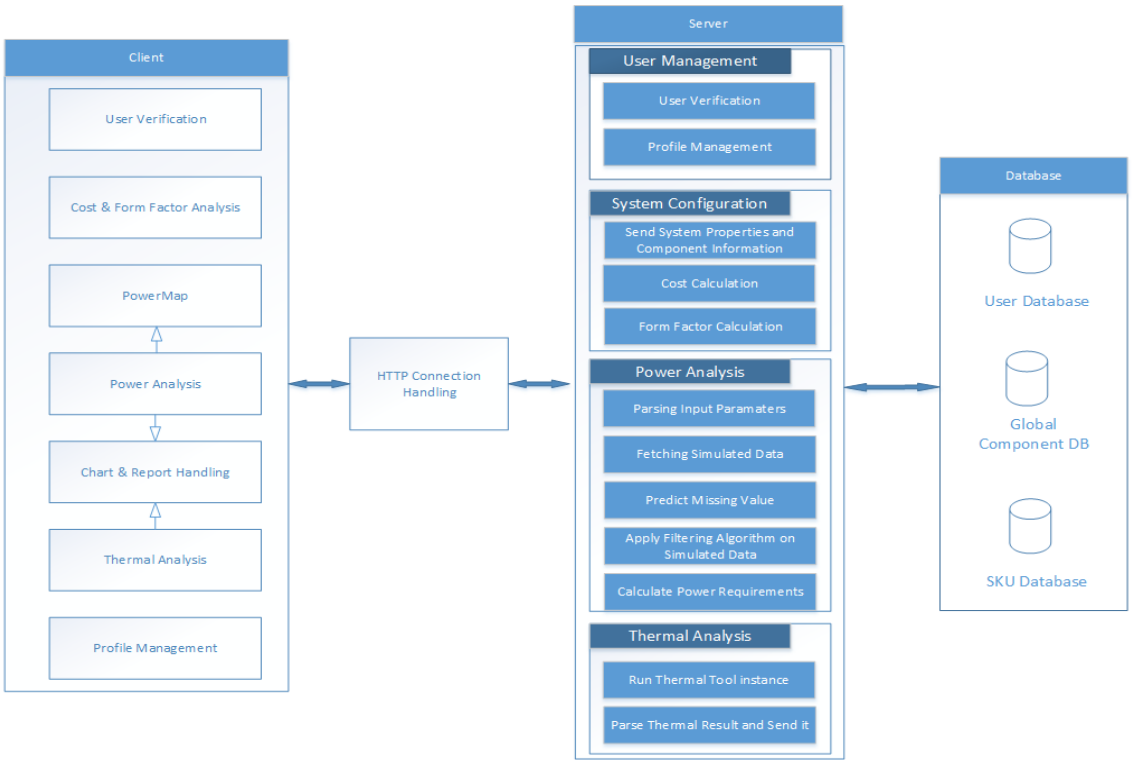

Figure 4.1: System Diagram

I **Client Side Module**

This module is developed using HTML5,CSS3 and AngularJS. For proper load balance and better performance, many server processes are moved at client side.

- **User Verification**

  User must be authenticated before loads. Tool uses NTLM authentication protocol to authentication and authorization.

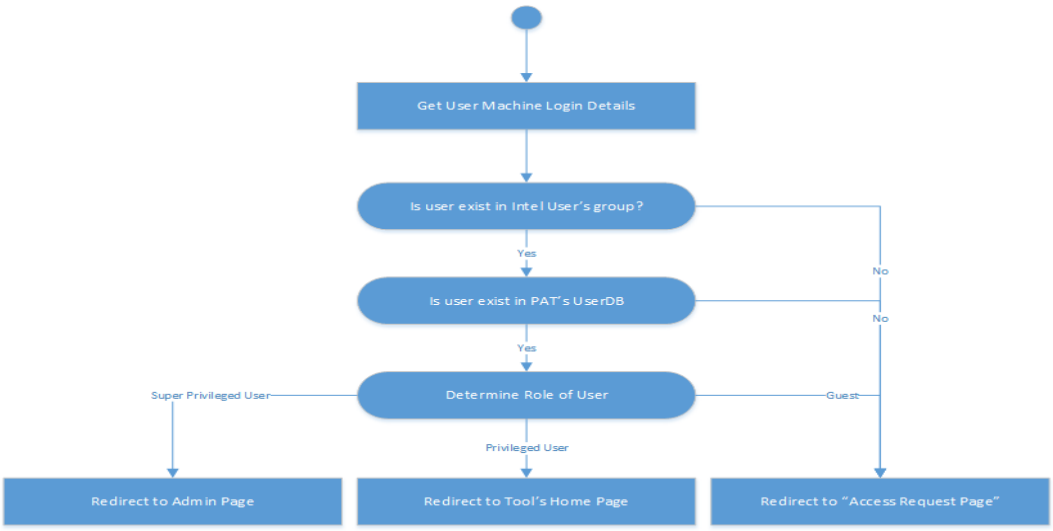

Figure 4.2: User Verification

Window NT Lan Manager (NTLM) is Microsoft network based authentication protocol that provide validation, authentication and privacy to client. Protocol collects user credentials from windows login and perform authentication.

- **Cost and Form factor Analysis**

  This module helps to select components within given cost limit. During tool loading, it fetches component information with cost information. User creates system configuration by selecting best option for each hardware module and pass system configuration to server for Cost and Form factor analysis. This module shows predicted device size information including thickness, width, height, overall system cost, battery life & size and SAR details.

- **Power Analysis**

  Power Analysis module takes system configuration and excepted benchmark scores as input and send it to simulator for analysis. Results of simulator are parsed and results are displayed here. This module shows

matching TDP-ICC pairs, Area details, Thermal dissipation power requirements,Power Map, different Power vs Score charts for comparative analysis and recommended devices for this configuration.

- **Power Map**

  PowerMap shows block diagram of power distribution across system. It also shows component-wise power consumption details with their rail details. This module allows to save Power Map in PDF format.

- **Chart and Report Handling**

  Data from simulator are passed to chart and Report handling module for better representation. For chart, we are using Canvas.js API and all numerical results are shown in tabular format.

- **Thermal Analysis**

  This Module communicates with external tool to get simulated thermal result. User invokes Thermal Tool instance and passing system configuration details as an arguments. After Thermal Tool simulation, it gives thermal analysis result as a JSON object.

- **Profile Management**

  This module is responsible for

  – Access control: Allows user to request for Tool access with normal privileges.

  – Configuration Settings Management: Allows to save, search and load system configurations from/to Cloud or File.

II **Server Modules:**

Actual Tool Logic is reside here,

- **User Management**

  This module communicates with User database and performs below activities

  - **User Verification:**
    * Add user request into User Database
    * Allows Admin to update user Role and Status
  - **Profile Management:**
    * Module allows user to save current configuration to be saved in cloud/disk. It converts current configuration into JSON object and saves it in database/file.
    * Enables user to search saved settings and load it into tool.
    * Settings can be saved either in private or public mode. Private settings can only be accessed by owner and public settings are open for all.

- **System Configuration** This module communicates with global catalog DB to fetch latest system components available in market and list of properties.
  - **Send System Properties and Component Information**
    When Tool loads, this module sends list of latest components and system properties details to client. Tool uses this information to guide user to built system configurations.
  - **Cost Calculation**
    Each sub components have their own cost. This module allows to build system with given cost limit.
  - **Form Factor Calculation**
    It accepts System components list and System properties as an input and gives X, Y, Z dimension information of target system.

- **Power Analysis**
  - **Parsing Input Parameters** Data received by module are not normalized. This function normalizes input data before processing it.

- **Fetching Simulated Data** SKU database contains verified simulated data and that data is used to get the best ICC and TDP values that satisfy conditions. This function fetches DB data and passes it to next function for processing.
- **Predict Missing Value** This is Machine Learning based regression algorithm that uses linear regression equation to predict missing values. Before applying regression, Database are divided into small datasets grouped by Memory, SKU and TDP value. Prediction algorithm are applied independently on that small set of dataset.
- **Apply Filtering Algorithm on Simulated Data** This function removes unnecessary rows from data set one by one. Row is unnecessary if it is unable to fulfill the score requirement. All the remaining rows are send back to client for further processing.
- **Calculate Power Requirements** Form above step, we get TDP-ICC pair. This TDP-ICC pair is use to calculate Area,Cost, Recommended devices and some PowerMap information.

• **Thermal Analysis** This module is use to invoke external Thermal tool for simulation

- **Run Thermal Tool instance** System Configuration input is passed to external tool for simulation. Tool will wait until simulation complete. result of simulation is passed to next module for parsing.
- **Parse Thermal Result and Send it** Result received from simulation is not properly formatted, this module receive this result and parse it into JSON object and send back to client.

III **Database** Tool refers 3 different database to get complete information

(1) **User Database:** User database contains information about authenticated users and their saved settings.

(2) **Global Component Database:** GCC Database contains information about latest component and sub-component information with cost and vendor information. This Database is not handled by this tool, tool uses it only for reading purpose.

(3) **SKU Database:** SKU database contains simulated Performance data with various system configuration.

4.2 Data Parsing

A. *XML Parsing*

Extensible Markup Language (XML) is a simple, very flexible text format derived from SGML. Tool uses below XML structure to store designing information.

```
<?xml version="1.0" encoding="UTF-8"?>
<Information>
  <component name="Name Of Components">
    <subComponent name="Control Name" type="DropDown">
          <item value="value 1"
            description="description Text 1">Text 1</item>
      <item value="value 2"
        description="Description Text 2">Text 2 </item>
    </subComponent>
  </component>
  <component name="ComponentName_2">
    <subComponent name="NameOfBenchmark" type="SeekBar"
        minValue="0" maxValue="100">
            Name Of Benchmark
        </subComponent>
    <subComponent name="NameOfBenchmark" type="SeekBar"
```

```
            minValue="0"  maxValue="100">
                Name Of Benchmark
            </subComponent>
    </component>
</Information>
```

Tool will parse above XML file and group them in such way that all controls of component are placed in same group. There is separate Tab panel created for each group. During system initialization, it will first parse XML file, categorize components and design GUI accordingly. If error produced during parsing, it prompts user to input correct XML file. Here we use DOM parsing to parse XML data and whole parse results are stored in class hierarchy.

Advantages of XML

- Namespaces allow for sharing of standard structures.
- Better representation for inheritance.
- Standard ways of expressing the structure of the document: XML schema, DTD, etc.
- Parsing standards: DOM, SAX
- Standards for querying: XQuery and XPath
- Standards for transforming a document: XSLT

B. *JSON Parsing*

Most of the data transfer between client and server is done in JSON string format. AngularJS parses these data and convert it into angular variables so that it can be easy to bind with HTML controls. Sample Format for component DB conversion into JSON string is as below

```
[{
    "controlName":"Display",
```

```
        "items":
        [
            {   "name":"15.6 inch eDP LCD Screen",
                "cost":"$50",
                "powerConsumption":"10W"
            },
            {   "name":"12.6 inch eDP LCD Screen",
                "cost":"$39",
                "powerConsumption":"8W"
            },
            {   "name":"8 inch eDP LCD Screen",
                "cost":"$50",
                "powerConsumption":"10W"
            }
        ],
        "default":"15.6 inch eDP LCD Screen"
    },
    {
        "controlName":"Memory",
        "items":
        [
            {   "name":"DDR3 4GB RAM",
                "cost":"$20",
                "powerConsumption":"3W"
            },
            {   "name":"DDR3 8GB RAM",
                "cost":"$31",
                "powerConsumption":"3W"
            },
```

```
            {    "name":"DDR4 4GB RAM",
                 "cost":"$25",
                 "powerConsumption":"2W"
            },
            {    "name":"DDR4 8GB RAM",
                 "cost":"$36",
                 "powerConsumption":"2W"
            }
        ],
        "default":"15.6 inch eDP LCD Screen"
}]
```

Advantages of JSON

- Light weight
- Easily integrated with javascript variables.
- well structured
- Can easily distinguish between the number and the string for example 1 as number and "1" as string.
- Can easily distinguish between single items and collections of size one (using JSON arrays).
- Easier to represent a null value.
- Human Readable

4.3 Snapshots

1. **Home Page**

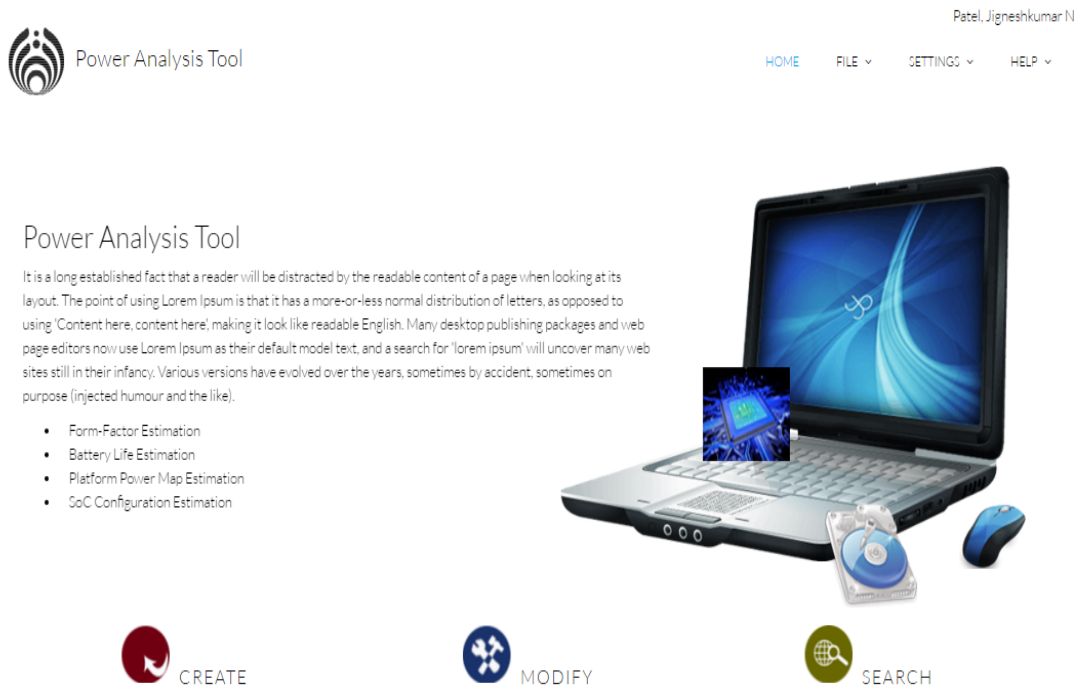

Figure 4.3: Tool Home Page

Before loading, It will fetch user details using windows NTLM authentication protocol and verify user permissions from User Database. If user has enough permission then only he can access the tool. After Authentication completed successfully, it will fetch and load System Component, Workload Information and System Properties details.

2. **System Component input Page**

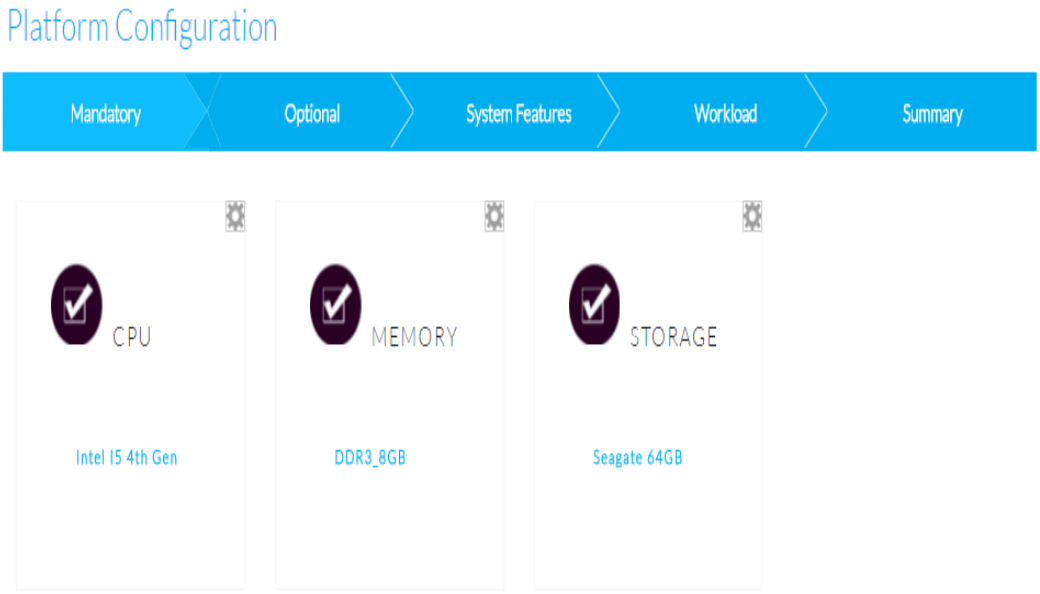

Figure 4.4: System Component inputs

This section helps user to define targeted system by picking a best subcomponent for each category. For proper arrangement and fast selection, Components are distributed into Mandatory and Optional group. By default, the best subcomponent in the category is selected. Setting button on top-right corner tells details description of component including subcomponent details,rails details and cost information.

3. **System Properties Input Page**

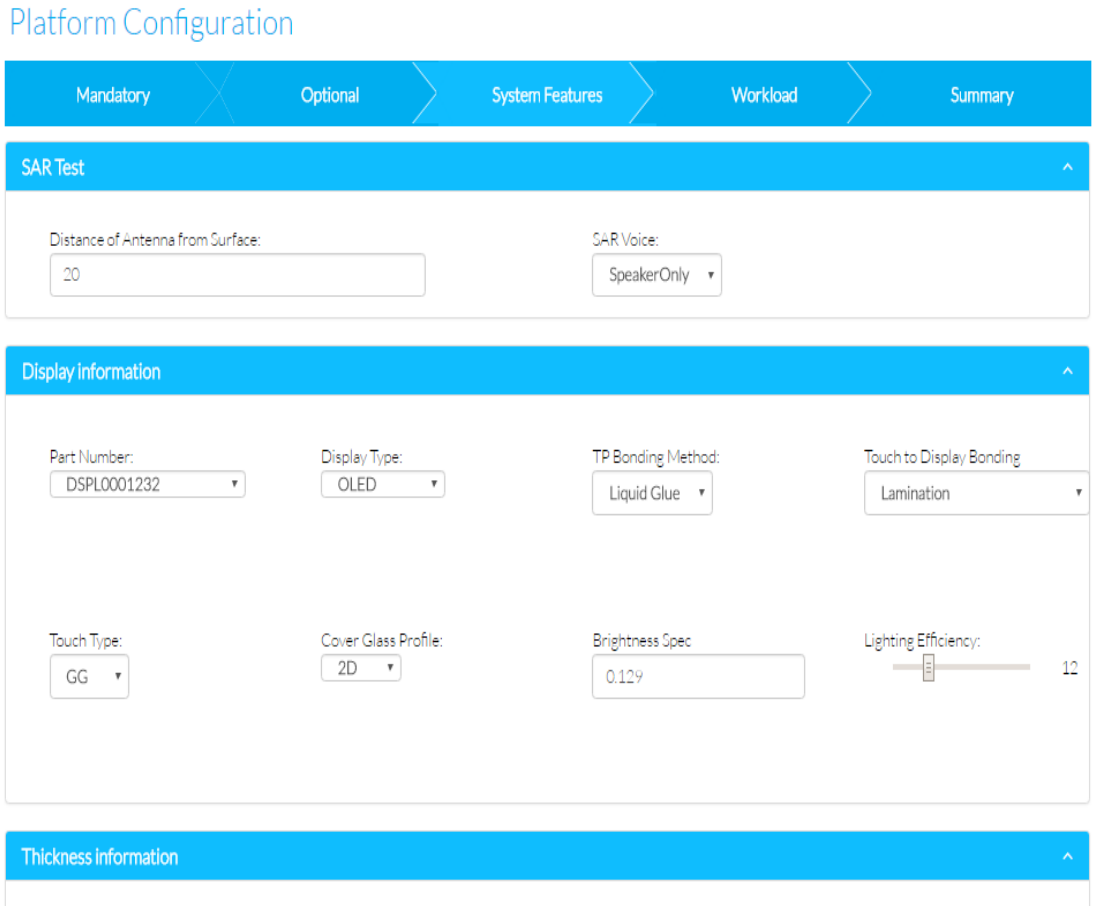

Figure 4.5: System Properties input Page

This section consists of system feature inputs like SAR (Specific Absorption Rate) Test details, Display component information and component thickness information. These inputs help to predict system form-factor information.

4. **Performance Requirement Page**

Figure 4.6: Performance Requirement Page

Workloads (Benchmarks) are grouped based on their type. Knob control enables user to select expected workload score within Min-max limit. This will help while calculating power and thermal requirements.

5. **Summary and Cost Calculation Page**

Figure 4.7: Summary and Cost Calculation Page

Whatever user had selected in all section are summarized here for verification. It also shows predicted final system cost which enables user to configure system upto some cost limit. Save button on top-right corner, allows to save current configuration in cloud or file. Estimate button will start simulation process and present results.

6. **Power Thermal Result Page**

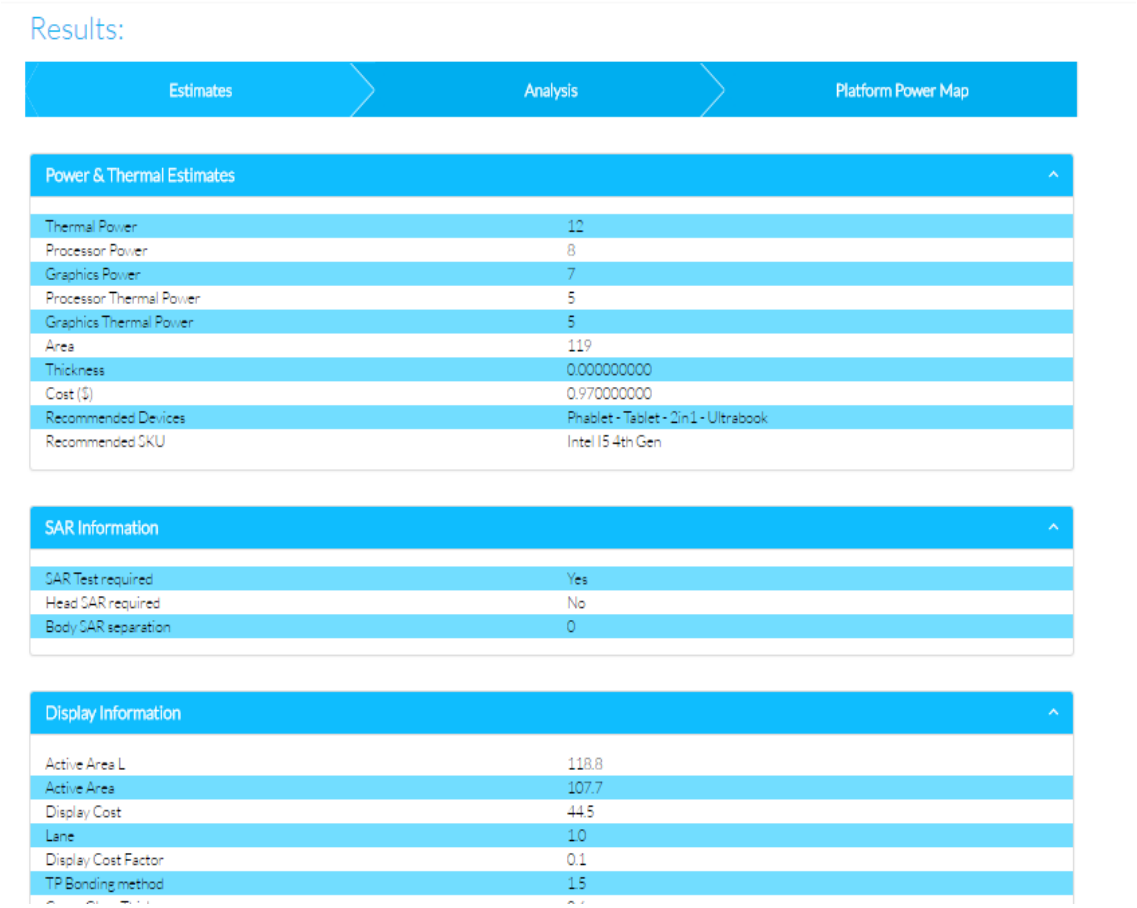

Figure 4.8: Power Thermal Result Page

Tabular Result of Form-factor, thermal and Power analysis results comes in this section.

- Power & Thermal Estimate shows
  - Power requirement for Processor and Graphics module
  - Thermal Power requirements for Entire System, Processor and Graphics
  - Processor form-factor information, recommended devices with this configuration

- SAR Information

  It tells which SAR tests require for device and suggested separation of device from body

- Display

  Expected display areas, bonding methods, power consumptions etc are come in this section

- Thickness

  It shows Device Area information like Battery cover thickness,Total Board Area,Battery Thickness Required,Device Thickness etc. are come in this.

7. **Power Analysis Graphs Page**

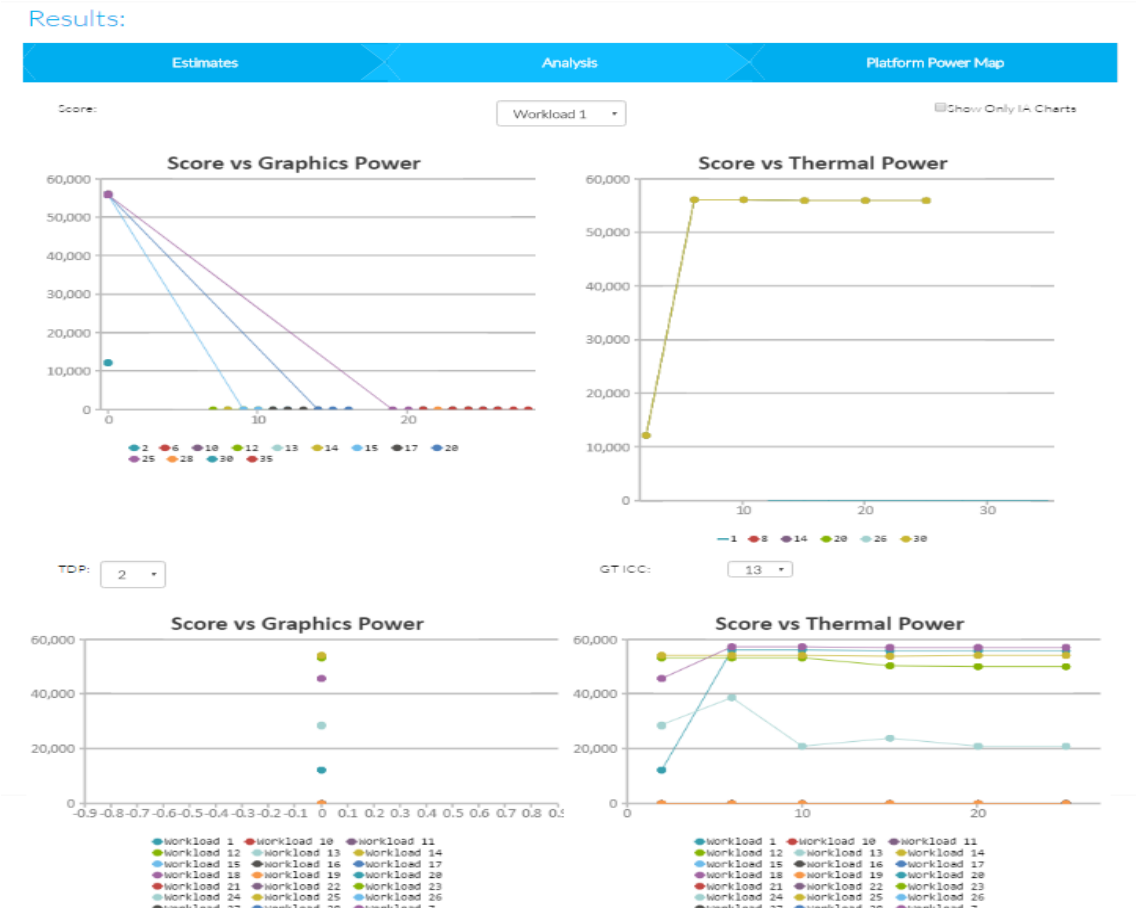

Figure 4.9: Power Analysis Graphs Page

Total 7 Power vs Score graphs enables user to do comparative power Analysis with various configuration option.

8. **Battery Life Analysis Page**

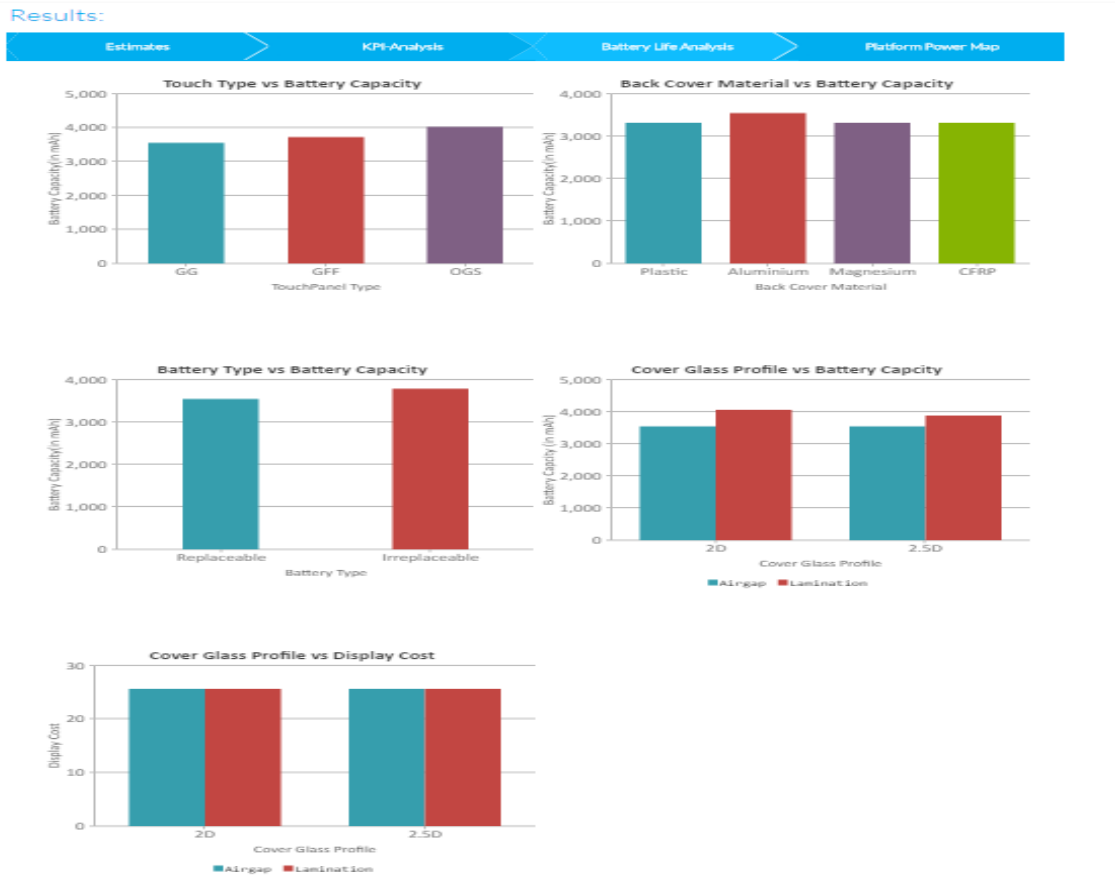

Figure 4.10: Battery Life Analysis Page

It shows predicted values of Battery Capacity and Display Cost at different variation of Touch Type, Cover Material, Battery Type (either replaceable or Irreplaceable), Cover Glass profile.

9. **Auto Calculation Panel**

Figure 4.11: Auto Calculation Panel

This floating panel gives quick view of important results and automatically update the result if any configuration changes happen.

10. **PowerMap Page**

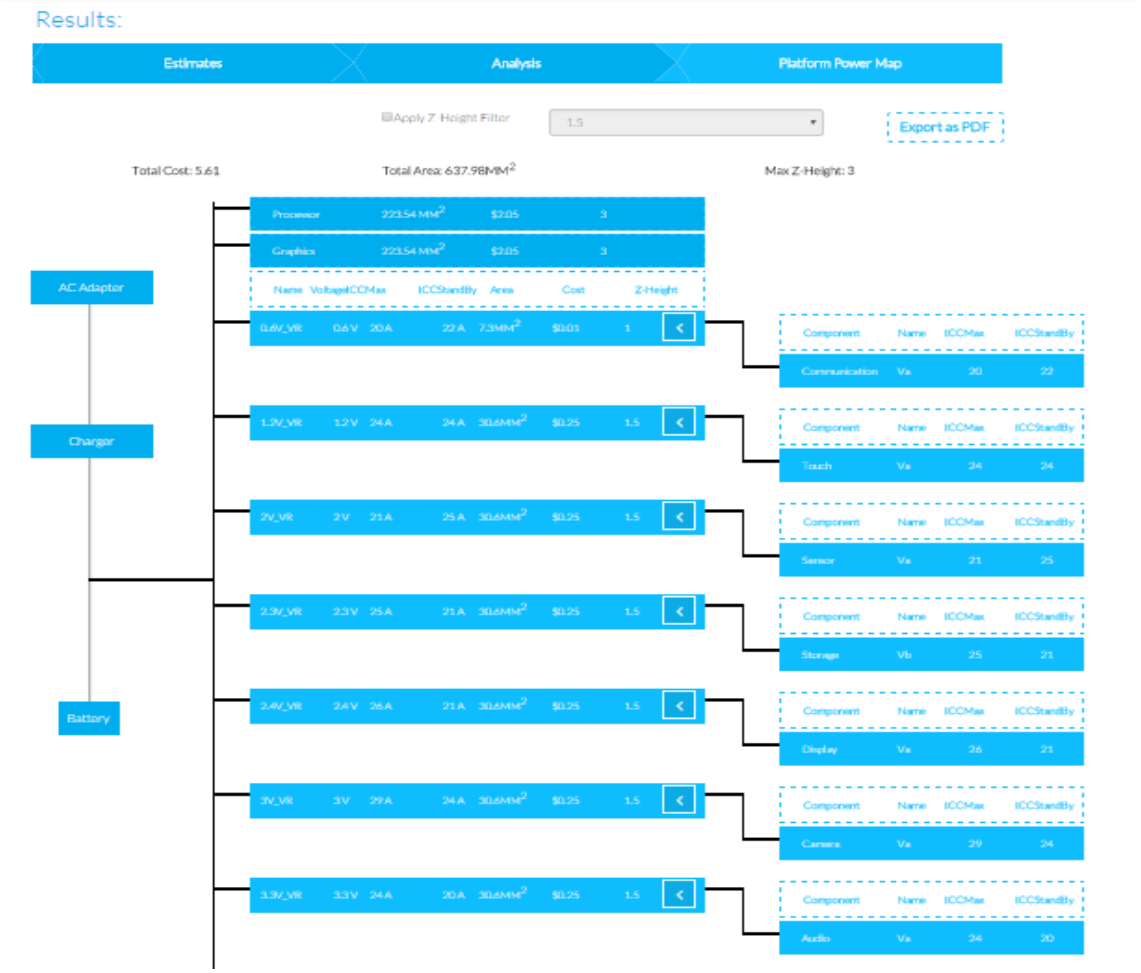

Figure 4.12: PowerMap Diagram

Form system configuration and expected system performance inputs, Simulator predicts power distribution information. Power Distribution details are converted into block diagram called PowerMap for better understanding.

11. **Save Current Configuration Page**

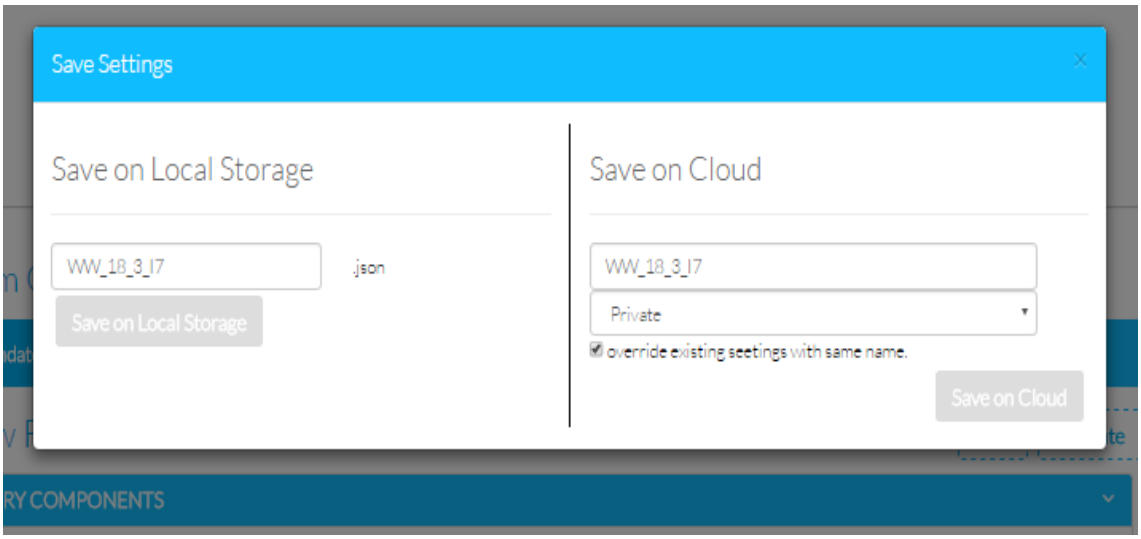

Figure 4.13: Save Current Configuration Page

This functionality allows user to save current configuration into cloud or file. If setting is saved with public access specifier then it can be accessed by all users. If overwrite checkbox is checked then current setting will overwrite existing settings if available.

12. **Load Settings Page**

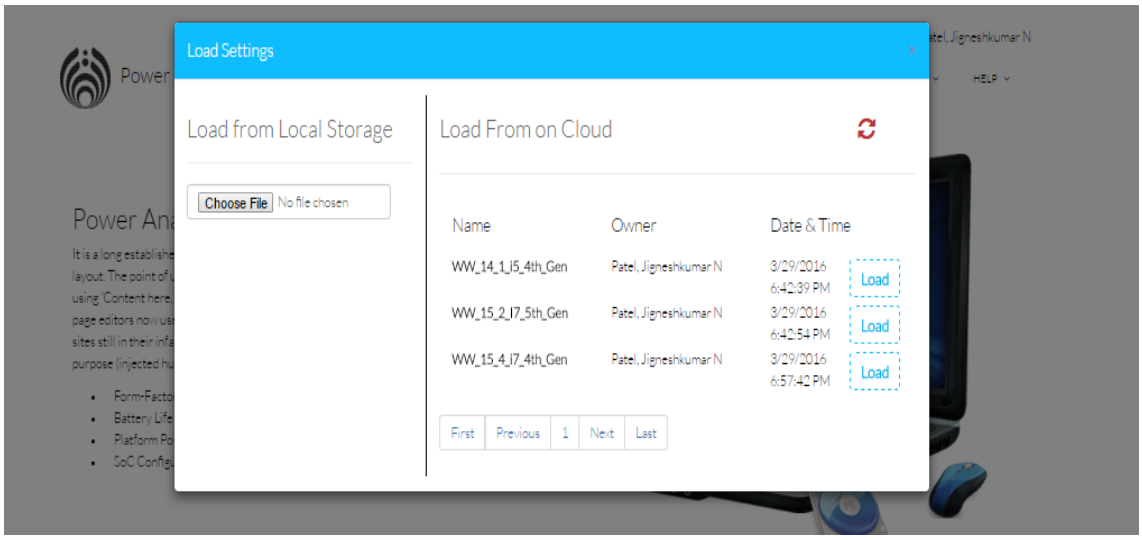

Figure 4.14: Load Settings Page

The Page allows user to restore previous tool configuration from cloud or file. It fetches list of saved settings from cloud and prompts user to load any one. User can also import his configuration file and start working from last restore point.

13. **Search Public Settings Page**

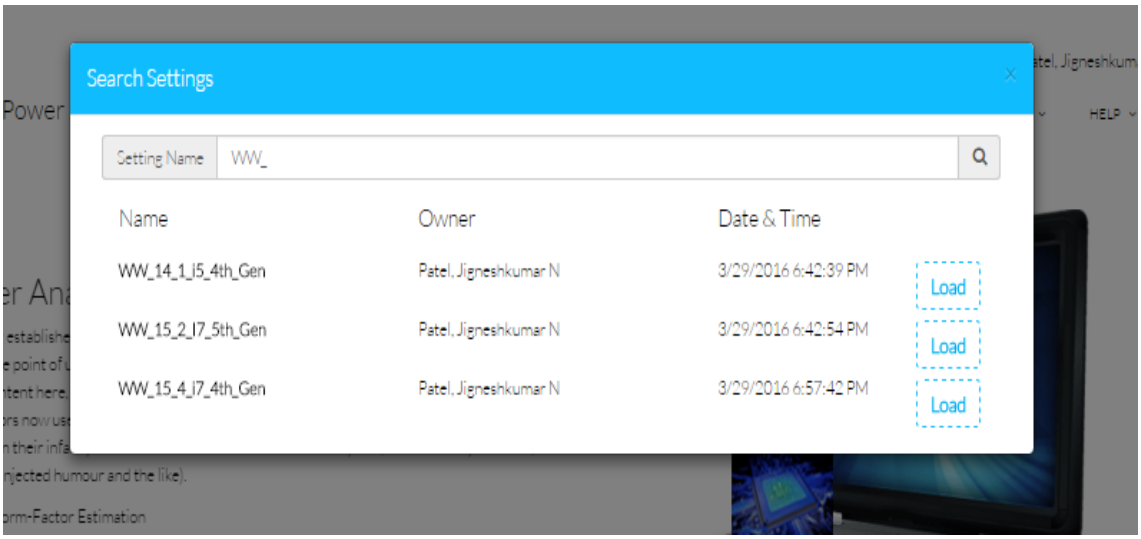

Figure 4.15: Search Public Settings Page

This is small search function which allows user to search stored public configuration from cloud and load it in tool.

14. **SKU Data Management Page**

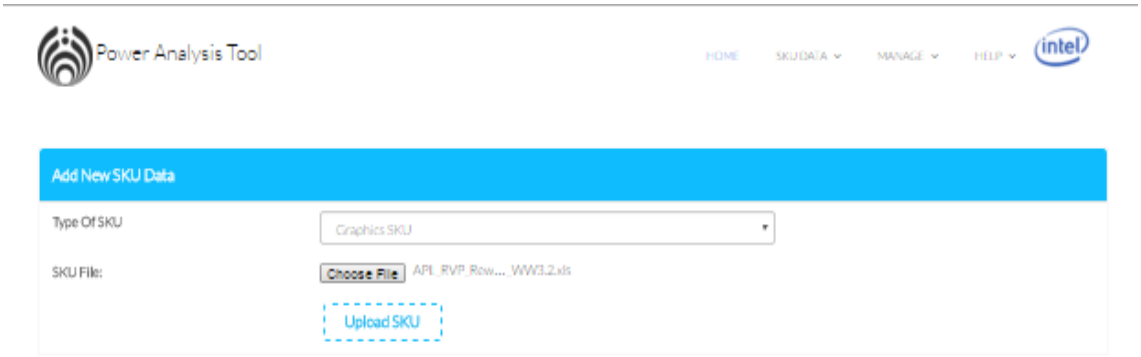

Figure 4.16: SKU Data Management Page

This page is only accessed by admin. SKU Data Management module enables admin to manipulate SKU database. User just needs to upload SKU file (Having predefine structure). Tool program will parse, insert/update values into database and run prediction algorithm for fill missing values. This module affects SKU Tables, Workload tables and TDP-ICC tables.

15. **Workload, User Management Page**

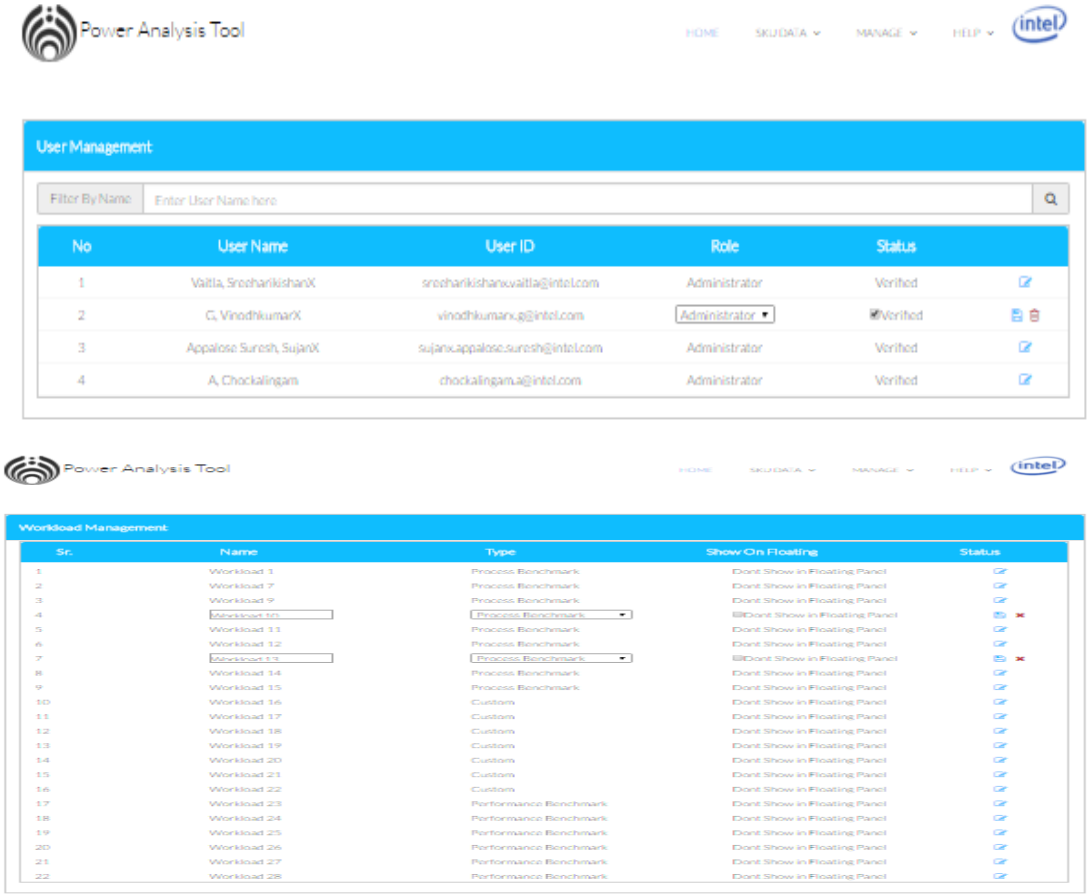

Figure 4.17: Workload, User Management Page

- **Workload Management Page:**

  Allows admin to rename workload, change its type and priority (High priority workloads will come in floating Panel).

- **User Management Page:**

  Allows admin to change user status, change user's role and delete user account from database.

16. **System Properties Management Page**

Figure 4.18: System Properties Management Page

This Admin Panel module manages System Properties values. Admin can add, update or delete values of SAR, Display and Thickness properties.

Chapter 5

Future Work

Tasks of Phase I are completed successfully. In next phase below modules will be completed

- Integration of Thermal Analysis tool (External Tool).
- Integration of Battery Life Analysis Tool.
- Integration of Workload Simulation Tool.

Chapter 6

Conclusion

6.1 Conclusion

Tool performs comparative analysis on simulated data and recommends best Power and Thermal configuration that will help engineer to design circuit with less effort, saves lots of time of designers and architectures and gives more accurate analysis than manual analysis. Various power analysis graphs in result help designer for further power analysis. Profile Management Module allows user to save and share his configuration with other users which helps to coordinate with team members. Battery Life Estimation and Cost Estimation modules provide wide range of alternatives to design system within given cost limit and battery life. Power distribution representation using PowerMap diagram makes system power consumption analysis easier.

Accuracy of estimation highly depends on accuracy and volume of SKU data. If data is too low or inaccurate, it won't be able to give complete prediction result. SKU Data is generated by external tool, so when new configuration comes, admin has to request data for that configuration. Indirectly success of the tool is highly depends on 'SKU Data Generator Tool'.

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