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Conceptual Design Tool for Aircraft Electrical System

Master Thesis

by

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Abbreviation

AC- Alternating Current

APU- Auxiliary Power Unit

ATA –Air Transport Association

CATIA- Computer Aided Three-dimensional Interactive Application

DC- Direct Current

KVA- kilovolt-ampere

MTOW- Maximum Take-off Weight

VBA- Visual Basic for Applications

Abstract

The conceptual design stage of an aircraft involves many uncertainties with regard to prediction of weight of systems. The current trend is that electrical systems increasingly replace hydraulic and pneumatic systems in an aircraft. This leads to greater uncertainty in weight, size and power requirement prediction.

This work is an attempt at developing a sizing tool that will allow users to estimate the power requirements and weight of electrical systems for a given size of an aircraft specified either by passenger capacity or by aircraft operating empty weight or by maximum take-off weight.

As with all predictive tools, the results of this work are based on currently available data, i.e., the specification of existing aircraft. This collection of specification of existing aircrafts would constitute the data library. The accuracy of the result of this work depends greatly on the variety of aircrafts and the level of detail for which the data is available.

The tool is made in Microsoft Excel with some codes made in VBA to perform Excel calculations.

Acknowledgement

This Master's thesis work was carried out in the Department of Management and Engineering, Division of Flumes at the Linköping University, Sweden. It was a great experience either to be a student or to work under the staff at the Division of Flumes. I would like to thank especially my supervisor Patrick Berry for his constant pursuit in obtaining materials necessary for this thesis work and providing valuable guidance throughout the course of work without which this would have not been possible. I also extend my gratitude to Christopher Jouannet and Edris Safavi for his timely guidance.

Friends and family have been my greatest source of motivation and support for which I would always remain indebted.

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Chapter-1 Introduction

1.1 The Aircraft Electrical System:

Aircrafts use hydraulic, pneumatic and electrical energy for various purposes. For example, bleed air from the engine is used in the Environmental Control System, hydraulics are used to drive the primary, secondary controls, landing gear and electrical energy is used to drive the avionics, lighting, in-flight entertainment, etc.

The use of electricity in aircrafts began from the technologies developed during World War II, where systems like radar were first used. Since that, the number and complexity of systems using electrical power has increased vastly. Initially the power system employed was 28V DC and with increase in load, 115V AC three phase alternator was used[1].

$$\text{Power} = \text{Voltage} \times \text{Current}$$

Equation 1 Power and Voltage relation

From the equation 1, it can be seen that by increasing the voltage, the amount of current transmitted can be reduced which means conductors of smaller diameter can be used to save weight. Also, voltage drops and power losses can be reduced.

In a typical commercial aircraft, electrical power is generated from generators connected to the turbine shaft of the engine. As there is requirement for both AC and DC power supply, a part of the generated power is converted either to DC via Transformer Rectifier Units or AC by inverters respectively. This is then distributed through supply system of wires called the busbars. They are separated into left, right and center busbars on most aircrafts with two or more than two generators[1].

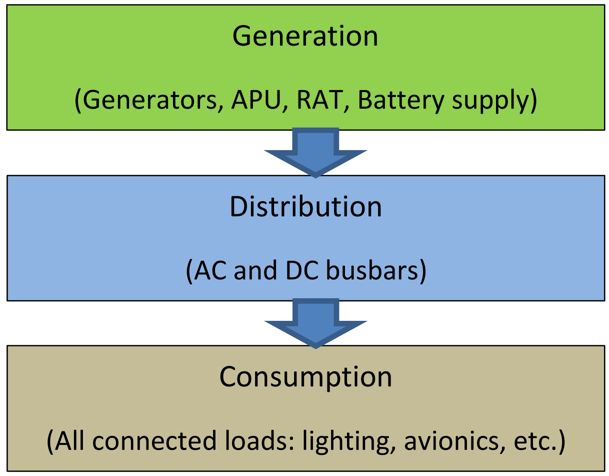

Figure 1 Aircraft Electrical System overview

The electrical circuit is built redundantly in such a manner that in the event of failure of one primary power source, the systems are powered from the remaining operational generators. The failed power source can be compensated by the remaining secondary sources, usually the APU. If all the primary and secondary sources fail, the vital controls are supplied from an emergency source like a battery back-up or a ram-air turbine or a generator powered by the emergency hydraulic reservoir.

1.2 The need for a sizing tool

The conceptual stage in design of a commercial aircraft begins with inputs such as payload capacity or number of passengers. The challenge at this stage is to establish the size and weight of the aircraft as per the requirements. With every new generation, engineers strive to reduce its operating empty weight.

Usage of composite materials instead of metal in construction of fuselage, replacing hydraulic and pneumatic systems with electrical systems contributes to significant savings in weight of structure and systems. Replacing hydraulic and pneumatic systems with electrical systems also improves the maintenance, reliability and running costs.

As the importance of electrical systems increases in aircrafts, so does the need to establish its sizing. This work attempts to estimate the weight of the electrical systems and also the power consumption according to the requirements such as MTOW, number of passengers or operating empty weight known in the conceptual stage.

Chapter-2 Theory

2.1 The Data Library:

The library would be a repository of information on electrical load analysis, specification of components constituting their power rating, their weight and physical dimensions for various types of aircrafts. This data library is at the core of the sizing tool as the results for the conceptual aircraft are estimated with the help of these available data.

2.2 Sizing of Power:

The electrical load analysis is studied for the power consumption of every component connected with the bus at every phase of flight and condition of the generators. The electrical load analysis chart is prepared by listing out all power sources depending on the condition of the generators for the phases of flight starting, taxiing, take-off, climb, cruise, approach and landing.

The power consumption does not remain a constant throughout the operation. It varies among components with each phase of flight. For example, components for landing gear operation consume the maximum power only during take-off and approach as only then they are operated. Services like anti-icing or de-icing is used only in adverse weather conditions and they do not contribute to usual load on the generators.

Power distribution also varies depending upon the condition of generators. In case of a twin engine aircraft, if any one of the generators fails, the APU could be used as a backup source. In the event of failure of all main generators, depending upon the configuration, the APU or a battery pack or even a ram air turbine would power the essential components.

Depending upon the generator condition, the amount and the busses to which power supply flows vary. These data are constructed in the library for the available aircrafts. These are then analyzed to provide the result for the conceptual aircraft.

2.3 Sizing of Weight and Size:

The weights and sizes of components could be estimated in the sizing tool by performing a regression analysis from the data of individual components of all the aircrafts available in the data library. This when correlated with the maximum take-off weight and the number of passengers, this would provide a weight and size estimate for the electrical system of the concept.

Chapter-3 Implementation- The Sizing Tool

3.1 The Data Library:

The library was constructed in Microsoft Excel using the electrical load analysis data of DC power consumption obtained for the aircrafts SAAB 340 and SAAB 2000. The weight split-up for the ATA 24 components of the SAAB 2000 were also obtained.

3.2 Power Consumption Analysis

The electrical distribution of the SAAB 340 and the SAAB 2000 are listed out and the power consumption figures for all states of the power source to the corresponding phase of flight are tabulated for both the aircrafts[2].

The user assigns the appropriate flight phase and the generator condition in the sizing input, the sizing tool then obtains the power consumption values for the SAAB 340 and the SAAB 2000 under similar conditions from the data library[3].

An assumption is made that an average of the obtained power consumption values could represent the value for an aircraft with passenger capacity of 46 and MTOW of 18,000 kg as an average value of passenger capacity and MTOW of both the aircrafts.

This helps to establish a ratio of power consumption with number of passengers, maximum take-off weight and operating empty weight respectively. This ratio is used to calculate the results for the conceptual aircraft.

A scatter diagram is constructed with available data from SAAB 340, SAAB 2000[3], Boeing 737-100 and Boeing 747-100 to predict the trend of change in DC power consumption value with change in MTOW and operating empty weight[4, 5]. This trend line equation is used to predict the values for a given conceptual aircraft.

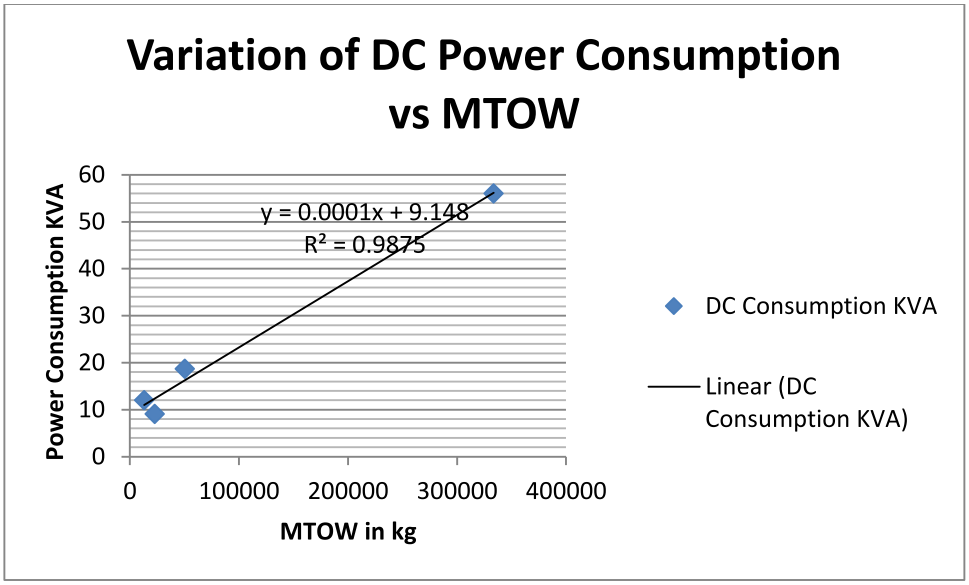

Figure 2 DC Power consumption vs. MTOW

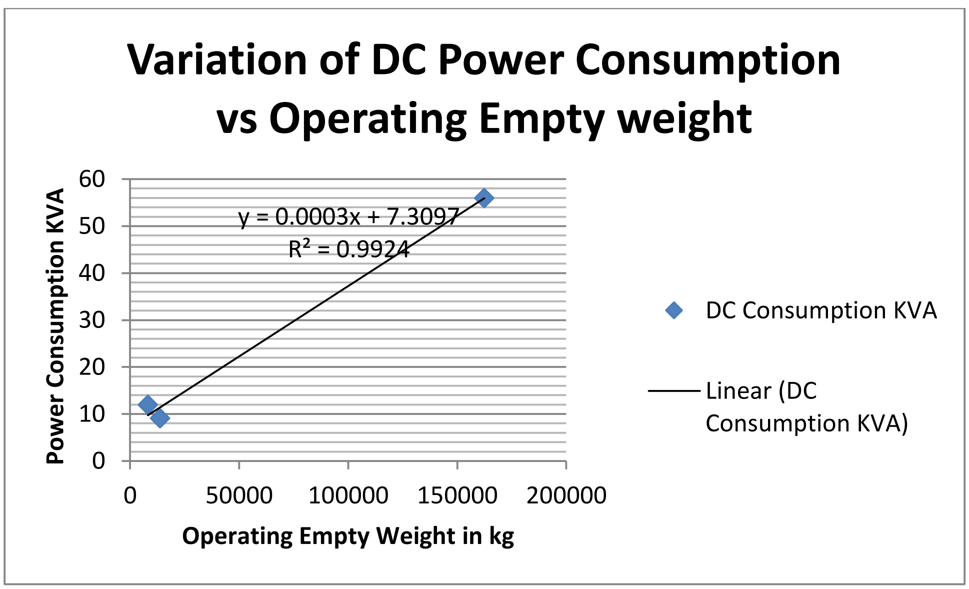

Figure 3 DC Power consumption vs. Operating Empty weight

3.3 Weight Prediction

The ideal method proposed for the weight sizing was to match the power rating of a component obtained from the power sizing value and then match it with its corresponding weight available from the regression analysis. Due to the severe constraints on the data obtained, this method was modified to estimate the weight from the Cessna method[6]. This estimated weight of electrical components is verified to be 95% accurate with the actual weight of the SAAB 2000 and hence this method is also adopted in electrical systems weight estimation of the SAAB 340. The Cessna method of weight estimation is given by the following equation[6]

$$W_{els}=0.0268*W_{TO}$$

Equation 2 Cessna method of electrical system weight estimation

Where,

W_{els} is the weight of electrical systems

W_{TO} is the take-off weight of the aircraft

With these values, a ratio of the electrical systems weight to the operating empty weight and maximum take-off weight of the aircrafts are made. These values could help establish the electrical systems weight were the designers would know the corresponding preliminary weights of the concept.

A scatter diagram is constructed with available data from SAAB 340, SAAB 2000, Boeing 737-100 and Boeing 747-100 to predict the trend of change in weight of electrical systems with change in MTOW and operating empty weight[4, 5]. This trend line equation is used to predict the values for a given conceptual aircraft.

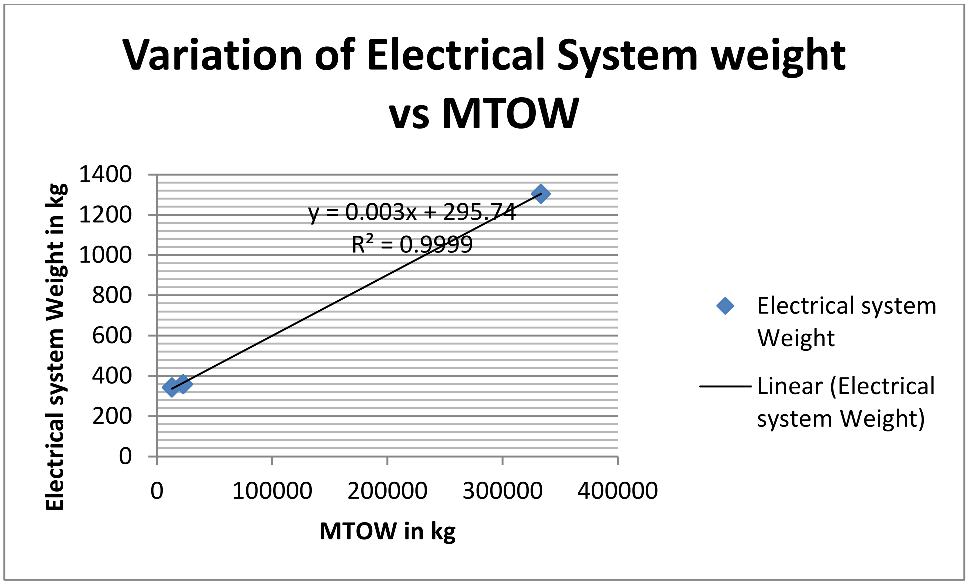

Figure 4 Electrical System weight vs. MTOW

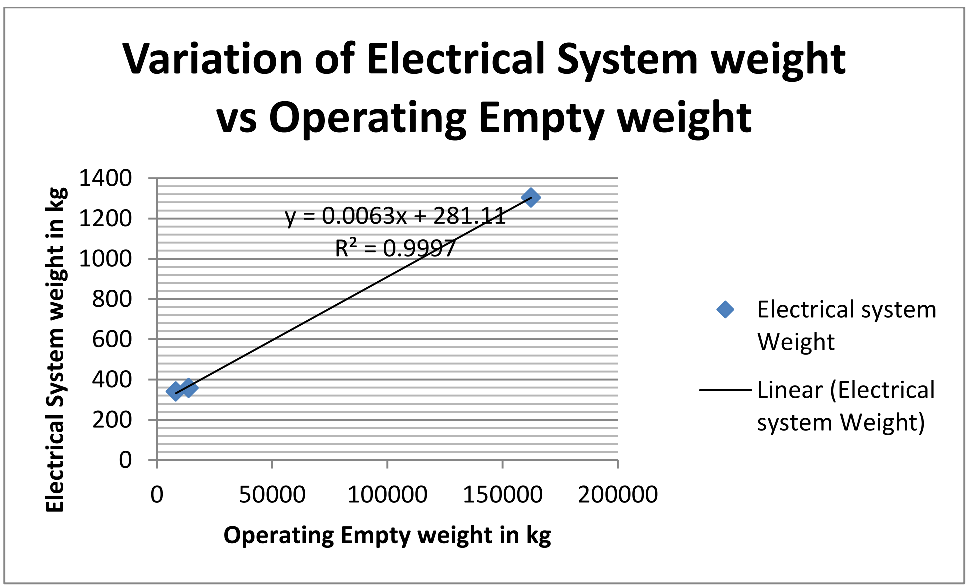

Figure 5 Electrical System weight vs. Operating Empty weight

Chapter-4 Results and Discussion

The sizing tool was used to predict the DC power consumption values and the electrical systems weight for some aircrafts with the inputs as passenger capacity, maximum take-off weight and operating empty weight[4, 7-9].

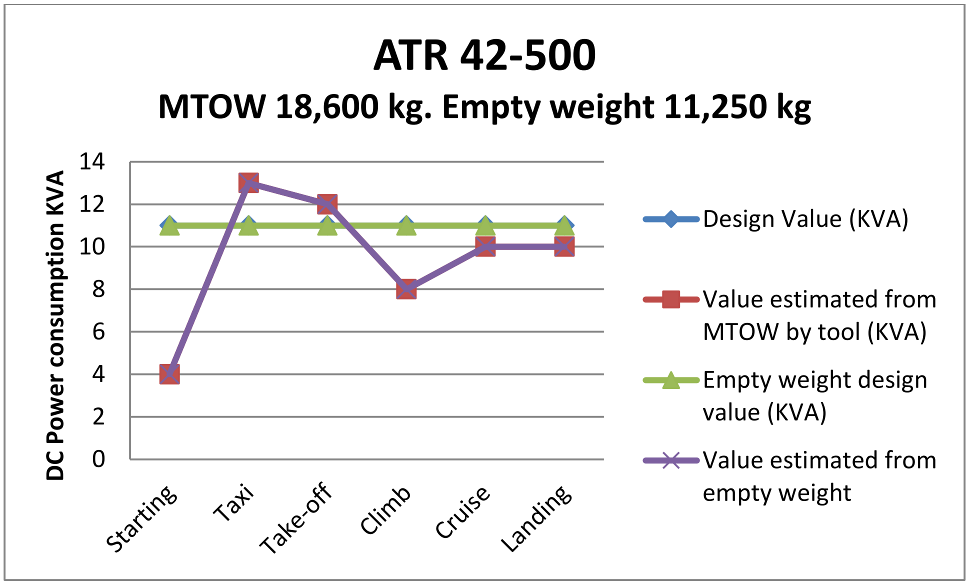

Figure 6 ATR 43-500 Simulation Result – DC Power Consumption

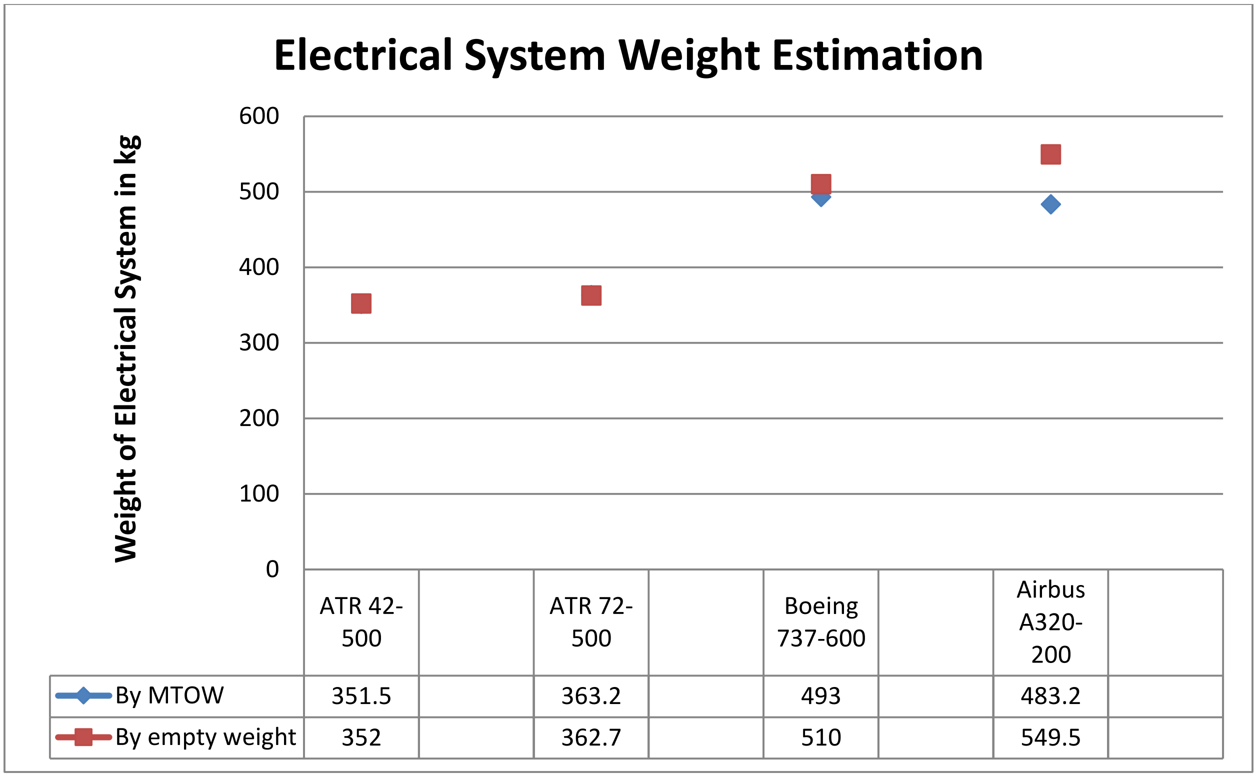

Figure 7 Simulation Result- Electrical System Weight Estimation

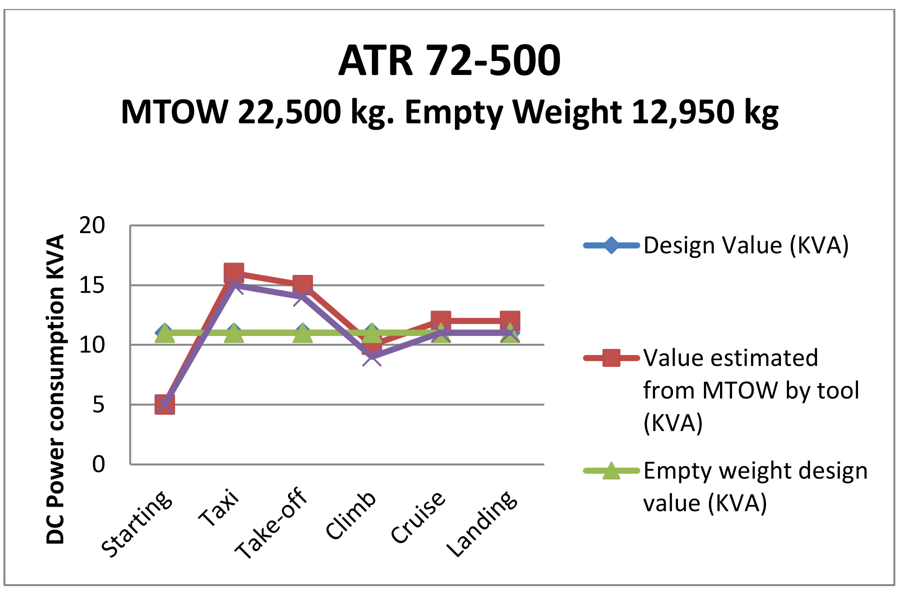

Figure 8 ATR 72-500 Simulation Result- DC Power Consumption

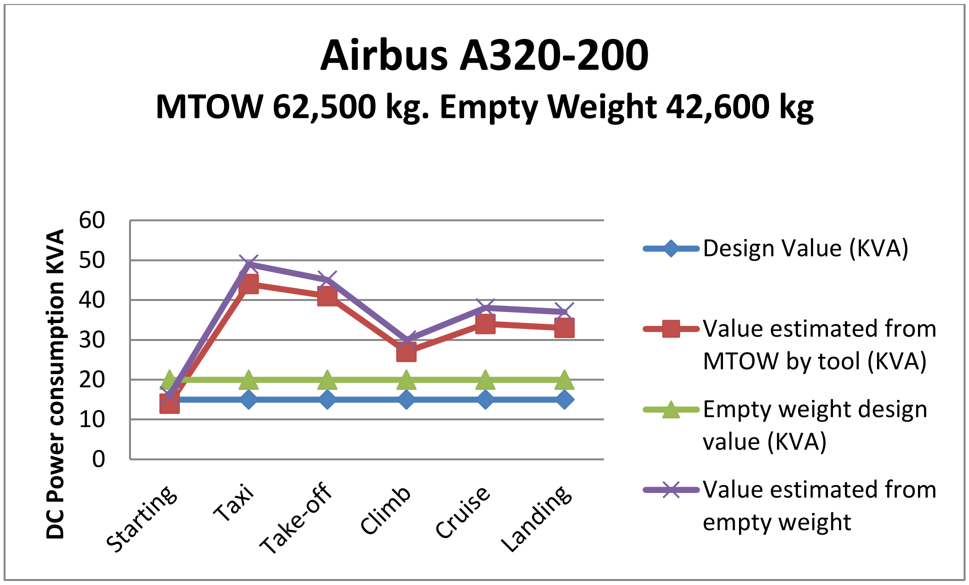

Figure 9 Airbus A320-200 Simulation Result- DC Power Consumption

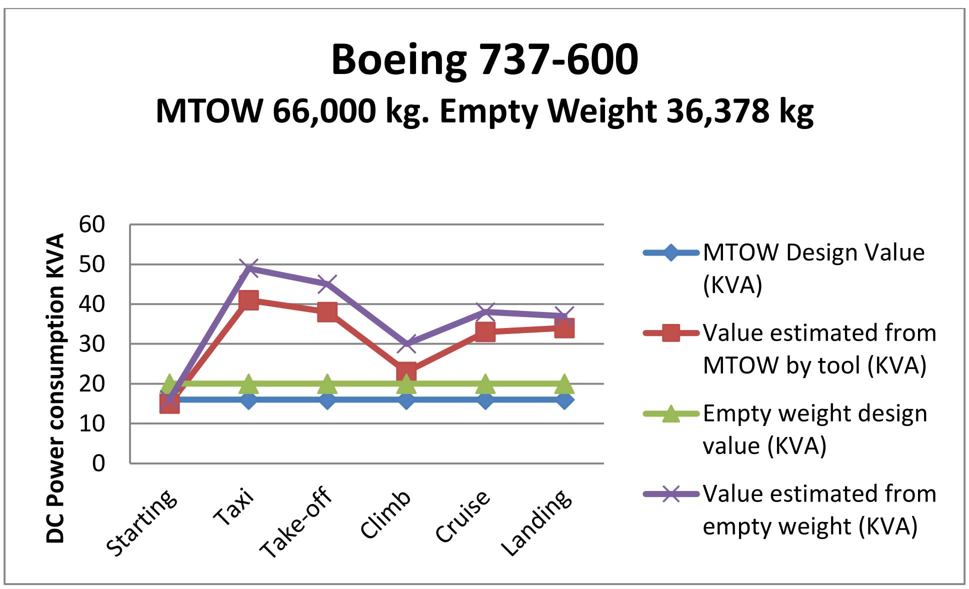

Figure 10 Boeing 737-600 Simulation Result- DC Power Consumption

From the DC power consumption analysis, it could be seen that the increase in difference between values estimated by the tool and actual values increases vastly with increase in the size of the aircraft. This can be due to the fact that the estimation is based on small aircrafts (i.e. MTOW less than around 25,000 kg). To improve the accuracy of prediction of the tool for bigger aircrafts like the Airbus A320, the library has to contain data for similar sized aircrafts.

Chapter-5 Conclusion and Future Work

The initial objectives of this work were to define the electrical system to proposed layout, with regard to redundancy aspects, power needed over time, weight and size of the system and its components. This system would not only be scalable with power needed but also it can be represented as a physical model in CATIA, to provide the designers an idea if the components would fit in the proposed size of the aircraft.

The objectives were revised to due to the limiting factors being the availability of data for the library construction. Currently, only the DC power consumption analysis data are available from manufacturers. More data like AC power consumption analysis, size, weight and power rating of individual components would have helped in the completion of the data library.

With a richer collection of library for a variety of aircrafts, the accuracy of the results will be greater. As the sizing tool considers only the DC power consumption values, it does not represent a clear picture in the results. Also, the ratio of consumption of AC and DC power differs between aircrafts since the DC power consumption of the SAAB 340 is more than the bigger SAAB 2000. Also, without any available data for other aircrafts to compare against, the results of this work are yet to be validated.

With the trend moving towards replacing more hydraulic and pneumatic systems with electrical systems, the electrical systems weight estimation also gains more significance. This work is in a very primitive stage, so are the methods used in the estimation. This can be used as a fundamental ground work on which a vastly improved sizing tool could be based upon.

References

[1] I. Moir and A. Seabridge, *Aircraft Systems*: Longman Scientific & Technical, 1992.
[2] SAAB, "SAAB 340B Aircraft Operations Manual."
[3] SAAB, "SAAB 2000 DC Load Analysis."
[4] Boeing. (05 June). *Boeing 737-600 Technical Characteristics*. Available: http://www.boeing.com
[5] Boeing, "Weight Prediction Manual - Class 1," 25 September 1968.
[6] J. Roskam, *Airplane Design Part 5*. Kansas: Roskam Aviation and Engineering Corporation, 1985.
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[8] ATR. (05 June). *ATR 42-500 Product Sheets-Operating Weight*. Available: http://www.atraircraft.com
[9] ATR. *ATR 72-500 Product Sheets-Operating Weight*. Available: http://www.atraircraft.com

Appendix

VBA Script

```
Sub Button5_Click()
Sheet5.Cells(18, 6).ClearContents
Sheet5.Cells(18, 7).ClearContents
Dim design_value As Integer
Dim flight_condition As Integer
    If Size.Cells(3, 2) > 0 And Size.Cells(4, 2) = 0 Then
    design_value = Round((Sheet5.Cells(99, 7) * Sheet5.Cells(7, 2).Value), 1)
    flight_condition = Round((Sheet5.Cells(7, 2) * (Sheet5.Cells(88, 2) + Sheet5.Cells(88, 3)) / 2), 1)
    Sheet5.Cells(18, 5) = "Total DC Power Consumption in KVA by Empty Weight "
    ElseIf Size.Cells(4, 2) > 0 And Size.Cells(3, 2) = 0 Then
    design_value = Sheet5.Cells(106, 7) * Sheet5.Cells(6, 2)
    flight_condition = Sheet5.Cells(6, 2) * ((Sheet5.Cells(89, 2) + Sheet5.Cells(89, 3)) / 2)
    Sheet5.Cells(18, 5) = "Total DC Power Consumption in KVA by MTOW"
    ElseIf Size.Cells(4, 2) = 0 And Size.Cells(3, 2) = 0 Then
    design_value = 0
    flight_condition = 0
End If
    Sheet5.Cells(18, 6) = Round(design_value, 2)
    Sheet5.Cells(18, 7) = Round(flight_condition, 2)
Dim S2000_Power_LHDC As Integer
Dim S2000_Power_RHDC As Integer
Dim S2000_Power_CNTRDC As Integer
Dim S340_Power_LHDC As Integer
Dim S340_Power_RHDC As Integer

If Size.Cells(17, 2).Value = 1 And Size.Cells(28, 2).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Starting "
```

```
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 3).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Taxiing "
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 4).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Take-off "
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 5).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Climb "
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 6).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Cruise "
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 9).Value = 1 Then
Sheet5.Cells(9, 2).Value = "Both Engines operational "
Sheet5.Cells(12, 2).Value = "Landing "
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 2).Value = 1 Then
Sheet5.Cells(9, 2).Value = "One generator operational "
Sheet5.Cells(12, 2).Value = "Starting "
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 3).Value = 1 Then
Sheet5.Cells(9, 2).Value = "One generator operational "
Sheet5.Cells(12, 2).Value = "Taxiing "
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 4).Value = 1 Then
Sheet5.Cells(9, 2).Value = "One generator operational "
Sheet5.Cells(12, 2).Value = "Take-off "
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 5).Value = 1 Then
Sheet5.Cells(9, 2).Value = "One generator operational "
Sheet5.Cells(12, 2).Value = "Climb "
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 6).Value = 1 Then
Sheet5.Cells(9, 2).Value = "One generator operational "
Sheet5.Cells(12, 2).Value = "Cruise "
```

```
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 9).Value = 1 Then

Sheet5.Cells(9, 2).Value = "One generator operational "

Sheet5.Cells(12, 2).Value = "Landing "

ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 2).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Starting "

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 3).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Taxiing "

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 4).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Take-off "

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 5).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Climb "

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 6).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Cruise"

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 9).Value = 1 Then

Sheet5.Cells(9, 2).Value = "Battery backup"

Sheet5.Cells(12, 2).Value = "Landing"

End If

''''''''''''LH DC

'normal engine operation

'APU START

If Size.Cells(17, 2).Value = 1 And Size.Cells(28, 2).Value = 1 Then

S2000_Power_LHDC = Sheet1.Cells(259, 8)

S340_Power_LHDC = Sheet3.Cells(204, 8)

S340_Power_RHDC = 0
```

```
'TAXI
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(259, 9)
S340_Power_LHDC = Sheet3.Cells(205, 9)
'TAKEOFF
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 4).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(259, 13)
S340_Power_LHDC = Sheet3.Cells(205, 13)
'CLIMB
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 5).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(259, 16)
S340_Power_LHDC = Sheet3.Cells(204, 16)
'CRUISE
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 6).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(259, 20)
S340_Power_LHDC = Sheet3.Cells(205, 21)
'LANDING
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(259, 24)
'S2000_Power_LHDC = Sheet1.Cells(260, 24)
S340_Power_LHDC = Sheet3.Cells(205, 26)
"""" one generator operational
'APU START
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 2).Value = 1 Then
S2000_Power_LHDC = 0
'TAXI
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(258, 11)
S2000_Power_RHDC = 0
S340_Power_LHDC = Sheet3.Cells(198, 11)
```

```
S340_Power_RHDC = 0
'S2000_Power_LHDC = Sheet1.Cells(259, 11)
S2000_Power_LHDC = 0
S2000_Power_RHDC = 0
SS340_Power_LHDC = 0
S340_Power_RHDC = 0
'TAKE OFF
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 4).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(258, 14)
S2000_Power_RHDC = 0
S340_Power_LHDC = Sheet3.Cells(198, 14)
S340_Power_RHDC = 0
'CLIMB
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 5).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(258, 18)
S2000_Power_RHDC = 0
'S2000_Power_LHDC = Sheet1.Cells(259, 18)
S340_Power_LHDC = Sheet3.Cells(198, 18)
S340_Power_RHDC = 0
'CRUISE
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 6).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(258, 22)
S2000_Power_RHDC = 0
'S2000_Power_LHDC = Sheet1.Cells(259, 22)
S340_Power_LHDC = Sheet3.Cells(198, 23)
S340_Power_RHDC = 0
'LANDING
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(258, 25)
S2000_Power_RHDC = 0
```

```
'S2000_Power_LHDC = Sheet1.Cells(260, 25)
S340_Power_LHDC = Sheet3.Cells(198, 27)
S340_Power_RHDC = 0
'battery operational
'APU START
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 2).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(256, 7)
S340_Power_LHDC = Sheet3.Cells(194, 7)
'TAXI
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_LHDC = 0
S340_Power_LHDC = 0
'TAKE OFF
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 4).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(256, 15)
S340_Power_LHDC = Sheet3.Cells(194, 15)
'CLIMB
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 5).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(256, 19)
S340_Power_LHDC = Sheet3.Cells(194, 20)
'CRUISE
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 6).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(256, 23)
S340_Power_LHDC = Sheet3.Cells(194, 25)
'LANDING
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_LHDC = Sheet1.Cells(256, 26)
S340_Power_LHDC = Sheet3.Cells(194, 28)
End If
```

```
'RH DC
'normal engine operational
'APU START
If Size.Cells(17, 2).Value = 1 And Size.Cells(28, 2).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 8)
S340_Power_LHDC = Sheet3.Cells(204, 8)
S340_Power_RHDC = 0
'TAXI
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 9)
'S2000_Power_RHDC = Sheet1.Cells(261, 9)
S340_Power_RHDC = Sheet3.Cells(206, 9)
'TAKEOFF
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 4).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 13)
S340_Power_RHDC = Sheet3.Cells(206, 13)
'CLIMB
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 5).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 16)
S340_Power_RHDC = Sheet3.Cells(206, 16)
'CRUISE
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 6).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 20)
'S2000_Power_RHDC = Sheet1.Cells(261, 20)
S340_Power_RHDC = Sheet3.Cells(206, 21)
'LANDING
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_RHDC = Sheet1.Cells(260, 24)
'S2000_Power_RHDC = Sheet1.Cells(261, 24)
S340_Power_RHDC = Sheet3.Cells(206, 26)
```

```
End If
'CTR DC
"""" battery supply
'APU START
If Size.Cells(17, 6).Value = 1 And Size.Cells(28, 2).Value = 1 Then
S2000_Power_CNTRDC = 0
'TAXI
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_CNTRDC = 0
'TAKE OFF
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 4).Value = 1 Then
S2000_Power_CNTRDC = 0
'CLIMB
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 5).Value = 1 Then
S2000_Power_CNTRDC = 0
'S2000_Power_CNTRDC = Sheet1.Cells(262, 16)
'CRUISE
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 6).Value = 1 Then
S2000_Power_CNTRDC = 0
'LANDING
ElseIf Size.Cells(17, 6).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_CNTRDC = 0
'normal engine operation
'APU START
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 2).Value = 1 Then
S2000_Power_CNTRDC = Sheet1.Cells(261, 8)
'TAXI
ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 3).Value = 1 Then
S2000_Power_CNTRDC = Sheet1.Cells(261, 9)
```

```
'TAKE OFF

ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 4).Value = 1 Then

S2000_Power_CNTRDC = Sheet1.Cells(261, 13)

'CLIMB

ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 5).Value = 1 Then

S2000_Power_CNTRDC = Sheet1.Cells(261, 16)

'S2000_Power_CNTRDC = Sheet1.Cells(262, 16)

'CRUISE

ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 6).Value = 1 Then

S2000_Power_CNTRDC = Sheet1.Cells(261, 20)

'LANDING

ElseIf Size.Cells(17, 2).Value = 1 And Size.Cells(28, 9).Value = 1 Then

S2000_Power_CNTRDC = Sheet1.Cells(261, 24)

'one engine operational

'APU START

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 2).Value = 1 Then

S2000_Power_CNTRDC = 0

'TAXI

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 3).Value = 1 Then

S2000_Power_CNTRDC = 0

'TAKE OFF

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 4).Value = 1 Then

S2000_Power_CNTRDC = 0

'CLIMB

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 5).Value = 1 Then

S2000_Power_CNTRDC = 0

'CRUISE

ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 6).Value = 1 Then

S2000_Power_CNTRDC = 0
```

```
'LANDING
ElseIf Size.Cells(17, 3).Value = 1 And Size.Cells(28, 9).Value = 1 Then
S2000_Power_CNTRDC = 0
End If
Sheet1.Cells(306, 2).Value = S2000_Power_LHDC
Sheet1.Cells(307, 2).Value = S2000_Power_RHDC
Sheet5.Cells(78, 3).Value = S2000_Power_CNTRDC
Sheet3.Cells(225, 2).Value = S340_Power_LHDC
Sheet3.Cells(226, 2).Value = S340_Power_RHDC
Sheet1.Cells(3, 8).Value = S2000_Power_CNTRDC
End Sub
```