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Development of a Computational Interface for Hydropower Plants

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Abstract The computational interface for hydropower plants was developed with Microsoft Visual Studio 2010 and tested using some available data from Jebba hydropower station to validate its functionality due to non availability of data for small hydropower plants which the interface is designed for. Hitherto several other methods have been used in hydropower computation, these methods range from manual computation with the use of pen and paper to the use of Microsoft Excel spreadsheet, some others utilize Visual Basic to commercial software. This interface was designed to compute flow duration values, plant capacity, power duration and the available energy. The program also have the project report feature, where user can view a concise report of the computation, save and print report sheets.

Keywords: *computational interface, manual computation, flow duration values, plant capacity, report sheets*

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1. Introduction

Hydroelectric power is the power generated from the energy of falling water. When water fall due to gravity, the kinetic energy thereof can be converted to mechanical energy and then to electrical energy which is the most usable form of energy [1].

Small hydropower plant does not have a universal definition due to differences in what is accepted to be 'small' in different countries, but generally a small hydropower plant can be described to be a plant that can generate between 1MW to 50MW [2]. Thus, any plant capacity above the stated value may be considered as large hydropower plant.

It is essential to make necessary computations to determine the operating conditions of any hydroelectric station. It is from such computation that some details of the plant such as plant capacity, flow duration values and curves, renewable energy available can be obtained [3].

Before a hydropower plant design and construction is fully started, there is a great need to obtain the flow duration data which is used to generate the flow duration curve, this is referred to as hydrological modeling [4], and the power duration curve is also of equal importance. At this stage the outcome of the calculation helps to determine whether the whole project is worthwhile or not, especially when it is compared with cost and power demand.

It is necessary to make hydropower calculations because:

i. It can be used to predict the expected output of a hydropower plant
ii. It is efficient in determining the future flow characteristics of the site
iii. For existing sites that are not performing optimally, the parameters can be checked to study why there is drop in output and how best to boost the output.

Furthermore the computational interface is even more important because:

i. It presents a fast and more accurate means of design calculation when compared with manual estimation which on the other hand involves dealing with large figures that can easily induce human error.
ii. It is possible to easily compare values to study which one gives a closer output to the desired output without having to go through the rigorous activity of manual calculation.
iii. It presents an organized printable report which will help in construction and is also useful for future reference.

2.Materials and Methods

The Hydropower computation modules development process follows the general way of developing applications in Visual Basic express edition [5]. The process is as follows:

i. Planning the project: It is at this stage that the conceptual view of the program is gotten, its structure, target users and ultimately the purpose for which the program will be written.
ii. Creating the project: this is the creation of all files necessary for the application which is known as the project and when more than one is referred to, it is known as solution.

iii. Designing the User interface: it involves dragging various controls onto the design surface or form. Then the properties that define the appearance and behaviour of the form and the contents are set.
iv. Writing the code: this involves writing of the visual basic code that defines how the application behaves and interacts with the user.
v. Testing the code: it is possible to have bugs in the application, bugs are errors that disallow the application from producing desired results, it is from this stage that the application is tested and errors are removed or debugging.
vi. The program is then compiled in an executable format (.exe) extension which runs on windows operating system. The application is then ready for distribution.

Each interface has its own particular use, some of the interfaces are passive, and they neither accept data nor contribute to the actual computation, they are only necessary to aid the use of the application or give useful information about the application, while the other set of interfaces are active, they are indispensable during computation, without some of them, computations cannot be made while others aid the accuracy of the computations.

2.1. Description of Program Interface

There is a need for a deeper design understanding than the architectural design and configuration specification as it contains the procedural methods with which the inputs are transformed to output. The algorithm for the program is also developed, which contains step by step solution to the problem.

2.1.1. The Flow Interface

The flow form was designed to have a data grid view which displays data loaded into the application, it has two buttons, one for opening the open file dialog which helps in selecting the file to load while the other is the OK button for accepting the loaded data. The strength of this interface lies in its codes and after data has been loaded to the memory, they are sorted in descending order using the Bubble Sort Method [6], and a rank is given to each value, the ranking was programmed to give the same rank to equal values and skip the next rank depending on how many values are equal. This and the equation for calculating the percentage equaled or exceeded are available on the web [7]. The equation for calculating percentage equaled or exceeded is given as:

$$P = 100\ x\ \frac{M}{n+1} \quad (1)$$

where,
P = the probability that a given flow will be equalled or exceeded (% of time)
M = the ranked position on the list
n = the number of events.

3.1.2. The Design Flow/Gross Head, Percentage Specified, Residual Flow And Losses Interface

All these forms are designed and function in the same way, they have textboxes into which the user enters the needed data, and a button which when clicked accepts the input data and stores at for use on other forms. Design flow is the maximum flow the turbine can use, the Gross head is the height of the falling water from the turbine, the percentage specified is a percentage value whose corresponding available flow value is the firm flow, and the residual flow is the flow left in the river throughout the year for environmental reasons. The losses include [8]: transformer losses which is the loss that occur due to the matching of the generator voltage to that of the transmission line, this value varies from 1-2%, parasitic electricity losses which is the loss due to the use of some of the energy generated to power auxiliary equipments it varies from 1-3%, maximum hydraulic losses which is the energy that is lost as water flows through the water passages and varies from 2-7% for most small hydropower plants. The maximum tail water which is the maximum reduction in available gross head that will occur during time of high flows in the river and annual downtime losses which is the loss due to the plant downtime and it is used in the computation of annual renewable energy available, it varies from 4-6%.

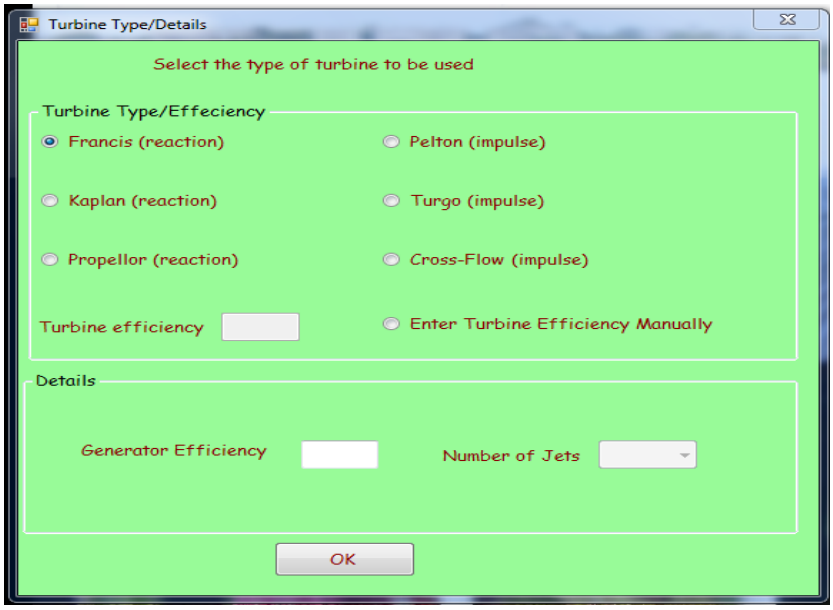


Figure 1. Turbine types interface

2.1.3. The Turbine Types Interface

This interface is responsible for accepting the user input of the type of turbine used, it has six radio buttons for the following types of turbine: Francis, Kaplan, Propeller, Pelton, Turgo and Cross flow Turbines. It also has a textbox for accepting manual efficiency which is enabled if the user decides not to use the model calculated efficiency and checks the enter efficiency manually radio button, the form also has a textbox that accepts the generator efficiency and a combo box for number of Jets which is used in the efficiency computation of Pelton and Turgo turbines.

2.2. Design Calculations

2.2.1. Turbine Efficiency

The Formulae for calculating the efficiency of the turbines are as given below [2]:

Reaction turbine runner size

$$d = kQ_d^{0.473} \tag{2}$$

where: d = runner throat diameter in m

$k = 0.46 \quad for \quad d < 1.8$

$k = 0.41 \quad for \quad d \geq 1.8$

Q_d = Design flow (flow at rated head and full gate opening in m^3/s)

Specific speed

$$n_q = kh^{-0.5} \tag{3}$$

where:

n_q = specific speed on flow

k = 800 for Kaplan and propeller turbines

k = 600 for Francis turbine

H = rated head on turbine in m

for Francis turbine:

Specific speed adjustment to peak efficiency:

$$\wedge e_{nq} = ((n_q - 56)/256)^2 \tag{4}$$

Runner size adjustment to peak efficiency:

$$\wedge e_d = (0.081 + \wedge e_{nq})(1 - 0.789d^{-0.2}) \tag{5}$$

Turbine peak efficiency:

$$e_p = (0.919 - \wedge e_{np} + \wedge_{ed}) - 0.0305 + 0.005R_m \tag{6}$$

where:

R_m = turbine manufacture/design coefficient

Peak efficiency flow:

$$Q_p = 0.65\, Q_d\, n_q^{0.05} \tag{7}$$

Efficiencies at flows below peak efficiency flow:

$$e_q = \left\{ 1 - \left[1.25 \left(\frac{Q_p - Q}{Q_p} \right)^{(3.94 - 0.0195 n_q)} \right] \right\} e_p \tag{8}$$

Drop in efficiency at full load:

$$\wedge e_p = 0.0072 n_q^{0.4} \tag{9}$$

Efficiency at full load:

$$e_r = (1 - \wedge e_p) e_p \tag{10}$$

Efficiencies at flows above peak efficiency flow:

$$e_q = e_p - \left[\left(\frac{Q - Q_p}{Q_d - Q_P} \right)^2 (e_p - e_r) \right] \tag{11}$$

for Kaplan and Propeller turbines:

Specific speed adjustment to peak efficiency:

$$\wedge e_{nq} = \left\{ (n_q - 170)/700 \right\} \tag{12}$$

Runner size adjustment to peak efficiency:

$$\wedge e_d = (0.0905 + \wedge e_{nq})(1 - 0.789d^{-0.2}) \tag{13}$$

Turbine peak efficiency:

$$e_p = (0.0905 - \wedge e_{nq} + \wedge e_d) - 0.0305 + 0.005 R_m \tag{14}$$

where:

R_m = turbine manufacture/design coefficient

for Kaplan turbines:

Peak efficiency flow:

$$Q_p = 0.75 Q_d \tag{15}$$

Efficiencies at flows above and below peak efficiency flow:

$$e_q = \left[1 - 3.5 \left(\frac{Q_p - Q}{Q_p} \right)^6 \right] e_p \tag{16}$$

for Propeller turbines:

Peak efficiency flow:

$$Q_p = Q_d \tag{17}$$

Efficiencies at flows below peak efficiency flow:

$$e_q = \left[1 - 1.25 \left(\frac{Q_p - Q}{Q_p} \right)^{1.13} \right] e_p \tag{18}$$

for Pelton turbines:

Rotational speed:

$$n = 31 \left(h \frac{Q_d}{j} \right)^{0.5} \tag{19}$$

i = number of jets (user – selected value from 1-6)

Outside diameter of runner:

$$d = \frac{49.4 h^{0.5} j^{0.02}}{n} \tag{20}$$

Turbine peak efficiency:

$$e_p = 0.864 d^{0.04} \tag{21}$$

Peak efficiency flow:

$$Q_p = (0.062 + 0.001 j) Q_d \tag{22}$$

Efficiencies at flows above and below peak efficiency flow:

$$e_q = \left[1 - \left\{(1.31 + 0.025j)\left|\left(\frac{Q_p - Q}{Q}\right)\right|^{(5.6+0.4j)}\right\}\right] e_p \quad (23)$$

for Turgo turbines:

$$\text{Efficiency} = \text{pelton} - 0.03 \quad (24)$$

for Cross flow turbines:

Peak efficiency flow:

$$Q_p = Q_d$$

Efficiency:

$$e_q = 0.79 - 0.15\left(\frac{Q_d - Q}{Q_p}\right) - 1.37\left(\frac{Q_d - Q}{Q_p}\right)^{1.4} \quad (25)$$

All these formulae were written into codes and during runtime the values they generate are sent to the home form for them to be accessed by other forms, the generator efficiency is stored as well.

2.2.2. The Plant Capacity

The computed capacity of the plant is done using the following equations [2]:

$$P_{des} = pgQ_{des}H_g(1 - l_{hydr})e_{t,des} \times e_g(1 - l_{trans})(1 - l_{para}) \quad (26)$$

where:

$P_{des} = Plant\ \ capacity$

$\rho = density\ \ of\ \ water$

$g = acceleration\ \ due\ \ to\ \ gravity$

$Q_{des} = Design\ \ head$

$H_g = gross\ \ head$

$l_{hydr} = \max imum\ \ hydraulic\ \ losses$

$e_{t,des} = turbine\ \ efficiency\ \ at\ \ design\ \ flow$

$e_g = generator\ \ efficiency$

$l_{trans} = transformor\ \ losses$

$l_{para} = parasitic\ \ electricity\ \ losses$

The power duration values are computed using each available flow duration value in the equation as Q

$$P_{des} = pgQ[H_g - (h_{hydr} + h_{tail})] \times e_t e_g(1 - l_{trans})(1 - l_{para}) \quad (27)$$

where:

$$h_{hydr} = H_g l_{hydr,\max}\frac{Q^2}{Q_{des}^2} \quad (28)$$

$l_{hydr,max}$ = maximum hydraulic losses specified by the user

$$h_{tail} = h_{tail,\max}\frac{(Q - Q_{des})^2}{(Q_{\max} - Q_{des})^2} \quad (29)$$

$h_{tail,\max} = \max imum\ tail\ water\ effect$

$Q_{\max} = \max imum\ \ water\ \ flow$

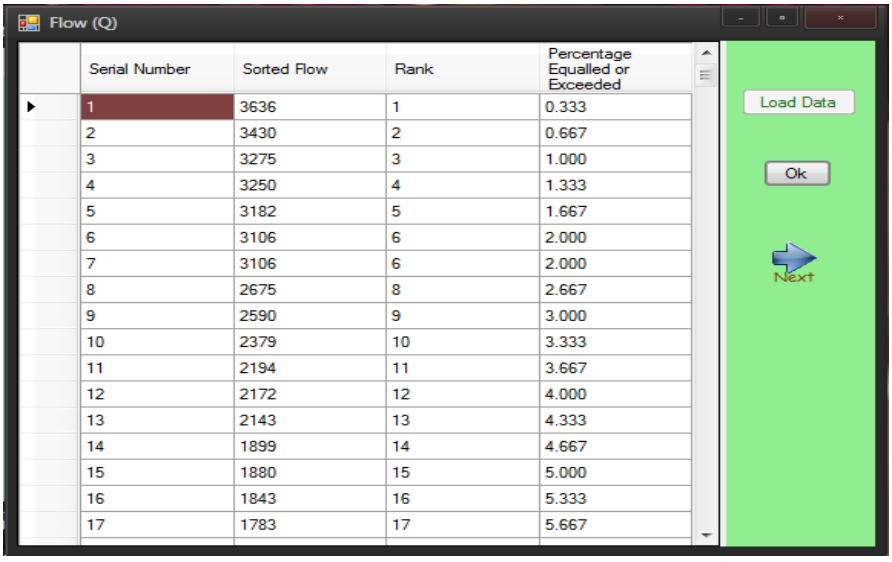
The renewable energy available is the area under the power duration curve and it is computed using the 21 values of power duration in the formula [2]:

$$E_{avail} = \sum_{k=1}^{20}\left(\frac{P_{s(k+1)} + P_{sk}}{2}\right)\frac{5}{100}8760(1 - l_{dt}) \quad (30)$$

where: l_{dt} is the is annual downtme losses.

3. Results and Discussion

The program interface requires real data from a functioning hydropower plant to ascertain its correctness. At this stage of the development of this interface program, data from Small Hydropower Plants (SHPs) would have been appropriate, however data from SHPs in Nigeria are either difficult to come by or are not available at all. The data of Jebba hydropower plant, Nigeria were obtained and used for the testing [9]. Although Jebba power plant is a large hydropower plant, using its data for testing is safe because the formulae for calculating the output of other sizes of hydropower plants are similar to that of small hydropower plant but additional losses need to be considered in the computation.



Serial Number	Sorted Flow	Rank	Percentage Equalled or Exceeded
1	3636	1	0.333
2	3430	2	0.667
3	3275	3	1.000
4	3250	4	1.333
5	3182	5	1.667
6	3106	6	2.000
7	3106	6	2.000
8	2675	8	2.667
9	2590	9	3.000
10	2379	10	3.333
11	2194	11	3.667
12	2172	12	4.000
13	2143	13	4.333
14	1899	14	4.667
15	1880	15	5.000
16	1843	16	5.333
17	1783	17	5.667

Figure 2. The loaded flow form

The input data used for the testing are:

i. The monthly flow data of the river Niger from 1984-2008

ii. Design flow of 380m^3/s [10]

iii. Head of 27.6m [11]

iv. Generator efficiency of 91%

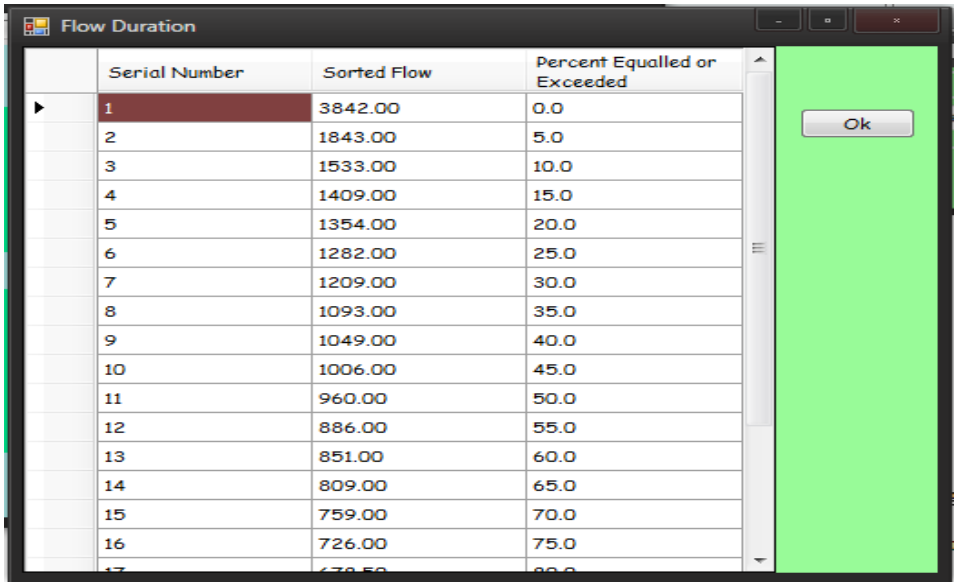
v. Fixed blade (propeller) type turbine

vi. Latitude = 9.138, Longitude = 4.7883 [12].

The losses, residual flow and percentage specified for firm flow were however not available. Nonetheless the program interface was however tested without these values because although they are necessary for accuracy, estimation can be made without them, moreover subsequently assumptions of the unavailable values within acceptable range was used to show that if the values were known, the result would have been closer to the actual value.

With all the necessary input obtained, the program was run and tested. From the flow form shown in Figure 2 below, it can be seen that a flow of 3275 m^3/s is obtainable from the site only at 1% of the time in a year; also a flow of 1880 m^3/s is obtainable at 5% of the time and so on.

It can be seen from the Figure 3 that the flow values have been arranged in 5% increment of percentage equaled or exceeded, these are the values needed for further computation.



	Serial Number	Sorted Flow	Percent Equalled or Exceeded
▶	1	3842.00	0.0
	2	1843.00	5.0
	3	1533.00	10.0
	4	1409.00	15.0
	5	1354.00	20.0
	6	1282.00	25.0
	7	1209.00	30.0
	8	1093.00	35.0
	9	1049.00	40.0
	10	1006.00	45.0
	11	960.00	50.0
	12	886.00	55.0
	13	851.00	60.0
	14	809.00	65.0
	15	759.00	70.0
	16	726.00	75.0

Figure 3. The flow duration values

Because residual flow was not entered it was passed as 0 to the application and that was what was subtracted from the flow duration values, hence the same values for the flow duration are for the available flow duration as well.

3.1. Flow Duration Curve

The flow duration and available flow duration have the same line because they share the same value. The flow duration curve obtained is depicted in Figure 4 below.

The following data were assumed with restriction to their range.

Percentage specified = 50%

Residual flow = 200m^3/s

Transformer losses = 0.0125

Parasitic electricity losses = 0.02021

Maximum hydraulic losses = 0.07

Maximum tail water effect = 1

Annual downtime losses = 0.04

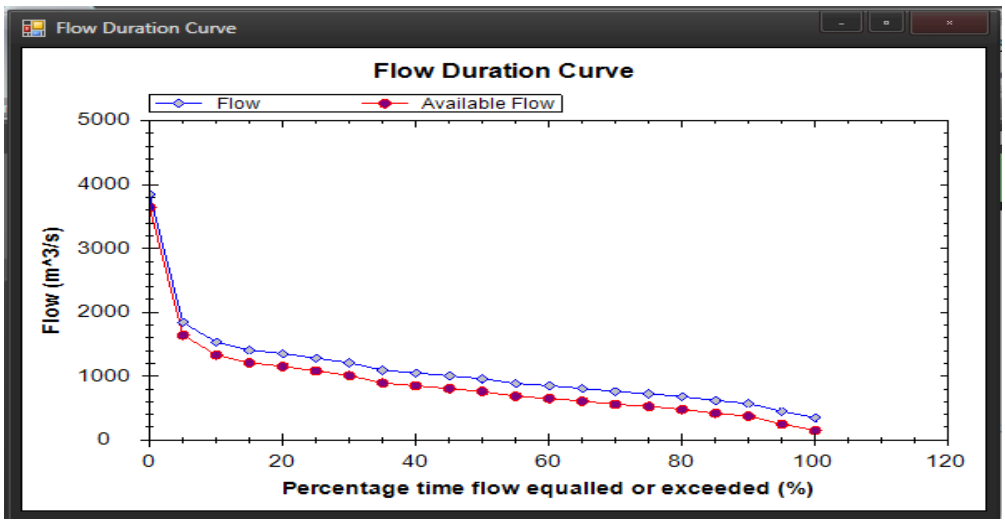


Figure 4. The flow duration curve

3.2. The Power Duration Curve

The power values were equal except the last value because any value larger than the design flow will not be used, rather the design flow will be used in its stead, this is because the turbine cannot utilize more than it is designed to use. This application plotted the curve using the power duration values as shown in Figure 5, and the area under this curve is the renewable energy available.

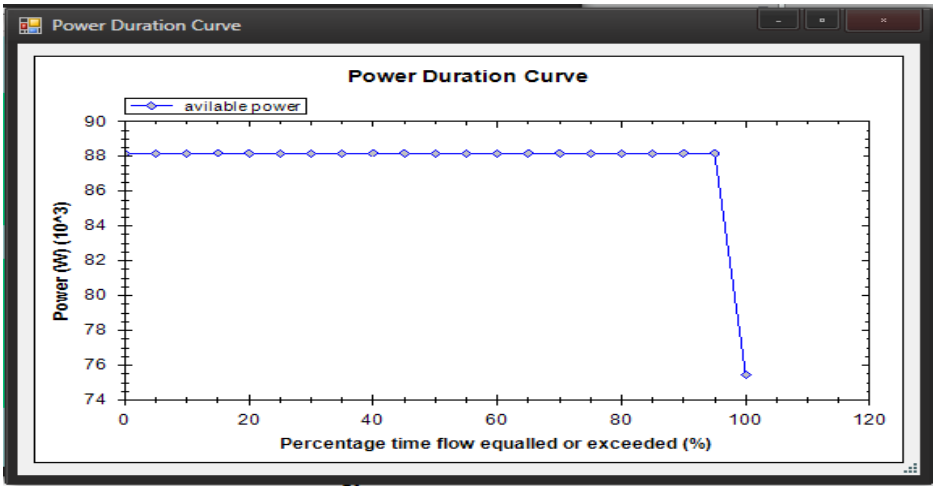


Figure 5. Power duration curve

Figure 6. Plant capacity

As shown in Figure 6 below, a plant capacity of 96,400.77kW was obtained which is similar to the 96.4MW that a unit turbine generates in Jebba.

The performance of the program interface was satisfactory as it was able to compute the flow duration values and curve, available flow duration value and curve, plant capacity, power duration values and curve, renewable energy available etc. When compared with other commercially available computational interface for hydropower plants, such as the No Outage Com LLC interface output, it offers comparable details and it is user friendly like both RETScreen and No Outage Com LLC. However the program interface has some limitations which include its inability to be used to compute the energy demand for isolated grid.

4. Conclusion

Hydropower computation interface is essential for any hydropower installation and accurate estimation is needed for detailed information on the expected output of the plant. This program interface has the capability of computing the output of hydropower plants in a short time, develop a reliable expected flow and power characteristics of the site and generate a comprehensive report of the computation that is printable. The limitations of the program interface include its inability to compute the renewable energy delivered to an off grid load.

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APPENDIX I

```
Flow form codes
Imports System.IO
Imports System.Text
Public Class FrmFlow
Public i As Integer
 Private Sub Button3_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button3.Click
 Dim openDialog As New OpenFileDialog openDialog.ShowDialog()
 Dim fileName As String
 fileName = openDialog.FileName.ToString()
 Debug.WriteLine(fileName.ToString())
 Dim builder As New StringBuilder
 Dim singleChar As String
 Dim intSingleChar As Integer
 Dim itemlist As New ArrayList
 Dim outWrite, outWrite2 As StreamReader
 Try
 outWrite = File.OpenText(fileName.ToString())
     outWrite2 = File.OpenText(fileName.ToString())
      Catch ex As Exception
      Beep()
      End Try
      'counting the entries
      Try
     While outWrite.Peek <> -1
     intSingleChar = outWrite.Read()
     singleChar = Chr(intSingleChar)
     " Debug.WriteLine(singleChar)
     If (singleChar.ToString() = "1") Then
           ElseIf (singleChar.ToString() = "2") Then
           ElseIf (singleChar.ToString() = "3") Then
           ElseIf (singleChar.ToString() = "4") Then
           ElseIf (singleChar.ToString() = "5") Then
           ElseIf (singleChar.ToString() = "6") Then
           ElseIf (singleChar.ToString() = "7") Then
           ElseIf (singleChar.ToString() = "8") Then
           ElseIf (singleChar.ToString() = "9") Then
           ElseIf (singleChar.ToString() = "0") Then
           ElseIf (singleChar.ToString() = vbNewLine Or singleChar.ToString() = vbCr) Then
      Else
      FrmHome.counter += 1
      End If
      End While
      Catch ex As Exception
      Debug.WriteLine(ex.ToString())
      End Try
      Dim counter2 As Integer
      counter2 = 0
```

```
    Try
    While outWrite2.Peek <> -1
            intSingleChar = outWrite2.Read()
            singleChar = Chr(intSingleChar)
            " Debug.WriteLine(singleChar)
            If (singleChar.ToString() = "1") Then
               builder.Append("1")
            ElseIf (singleChar.ToString() = "2") Then
               builder.Append("2")
            ElseIf (singleChar.ToString() = "3") Then
               builder.Append("3")
            ElseIf (singleChar.ToString() = "4") Then
               builder.Append("4")
            ElseIf (singleChar.ToString() = "5") Then
               builder.Append("5")
            ElseIf (singleChar.ToString() = "6") Then
               builder.Append("6")
            ElseIf (singleChar.ToString() = "7") Then
               builder.Append("7")
            ElseIf (singleChar.ToString() = "8") Then
               builder.Append("8")
            ElseIf (singleChar.ToString() = "9") Then
               builder.Append("9")
            ElseIf (singleChar.ToString() = "0") Then
               builder.Append("0")
  ElseIf (singleChar.ToString().Equals(vbNewLine) Or singleChar.ToString().Equals(vbCr) Or
singleChar.ToString().Equals(vbCrLf)) Then
            builder.Append("")
             Else
            FrmHome.arrayflow(counter2) = Double.Parse(builder.ToString())
               counter2 += 1
                builder.Clear()
          End If
          End While
          'bubble sort
          Dim counter3 As Integer
          counter3 = 1
          Dim k, l As Integer
          For k = 0 To FrmHome.arrayflow.Count - 2
          For l = k + 1 To FrmHome.arrayflow.Count - 1
          If FrmHome.arrayflow(k) < FrmHome.arrayflow(l) Then
          swap(FrmHome.arrayflow(k), FrmHome.arrayflow(l))
          End If
          Next
          Next
          Dim n, m As Integer
          FrmHome.rank1(n) = 1
          For n = 0 To FrmHome.arrayflow.Count - 2
          For m = n + 1 To FrmHome.arrayflow.Count - 1
          If FrmHome.arrayflow(m) = FrmHome.arrayflow(n) Then
          FrmHome.rank1(m) = FrmHome.rank1(n)
          Else
          FrmHome.rank1(m) = m + 1
          End If
          Next
          Next
          counter2 += 1
          i = 0
          DataGridView1.Rows.Clear()
          Do While (i < FrmHome.counter)
          FrmHome.calc = FrmHome.rank1(i) / (FrmHome.counter + 1)
          FrmHome.calc = FrmHome.calc * 100
          FrmHome.calcArray.Add(FrmHome.calc)
```

```
DataGridView1.Rows.Add(New String() {i + 1, FrmHome.arrayflow(i), FrmHome.rank1(i),
FrmHome.calc.ToString("0.000")})
            Debug.WriteLine(builder.ToString())
            Debug.WriteLine(i)
            i += 1
        Loop
        FrmHome.FlowDurationValuesToolStripMenuItem.Enabled = True
        Button3.Enabled = False
        FrmFlowDuration.flowduration()
      Catch ex As Exception
MsgBox("No/Wrong file selected", MsgBoxStyle.Exclamation, "Selection not Identified")
      End Try
  End Sub
  Private Sub swap(ByRef a As Integer, ByRef b As Integer)
      Dim temp As Integer
      temp = a
      a = b
      b = temp
  End Sub
Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
      Me.Hide()

  End Sub
  Private Sub FrmFlow_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
  End Sub
  Private Sub LinkLabel1_LinkClicked(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.LinkLabelLinkClickedEventArgs) Handles LinkLabel1.LinkClicked
      FrmResidualFLow.Show()
      Me.Hide()
      FrmResidualFLow.Visible = False
      FrmResidualFLow.ShowDialog(FrmHome)
  End Sub
  Private Sub DataGridView1_CellContentClick(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.DataGridViewCellEventArgs) Handles DataGridView1.CellContentClick
End Sub
End Class
```

Flow duration codes

```
Public Class FrmFlowDuration
  Public Sub availflow()
      FrmAvailFlow.DataGridView1.Rows.Clear()
      Dim i As Integer
      i = 0
      Dim val As Double
      val = 0
      Do While (i <= 20)
          Try
    FrmHome.arrayavailflow(i) = (FrmHome.resultarray.Item(i) - FrmHome.ResFlow)
          Catch ex As Exception

    MsgBox("please open the flow duration window first", , "Unable to load Data")
          Exit Sub
          End Try
          FrmAvailFlow.DataGridView1.Rows.Add(New String() {(i + 1), FrmHome.arrayavailflow(i).ToString("0.00"),
val.ToString("0.0")})
          i += 1
          val += 5
      Loop
  End Sub
  Public Sub flowduration()
      DataGridView1.Rows.Clear()
      Dim val As Double
      Dim val4, val5, val6, val7 As Double
      Dim i As Integer
```

```
        i = 1
        val = 0
        Do While (i <= 21)
            If val = 0 Then
                val4 = FrmHome.calcArray.Item(0)
                val5 = FrmHome.calcArray.Item(1)
                val6 = FrmHome.arrayflow(0)
                val7 = FrmHome.arrayflow(1)
                FrmHome.result = ((val - val4) * (val7 - val6)) / (val5 - val4)
                FrmHome.result = FrmHome.result + val6
            ElseIf val = 100 Then
                val4 = FrmHome.calcArray.Item(FrmHome.calcArray.Count - 1)
                val5 = FrmHome.calcArray.Item(FrmHome.calcArray.Count - 2)
                val6 = FrmHome.arrayflow(FrmHome.calcArray.Count - 1)
                val7 = FrmHome.arrayflow(FrmHome.calcArray.Count - 2)
                FrmHome.result = ((val - val5) * (val6 - val7)) / (val4 - val5)
                FrmHome.result = FrmHome.result + val7
            Else
                Dim val3 As Integer
                val3 = FrmHome.calcArray.IndexOf(val)
                If val3 < 0 Then
                    For Each calc1 As Double In FrmHome.calcArray
                        If val > calc1 Then
                            val4 = FrmHome.calcArray.Item(FrmHome.calcArray.LastIndexOf(calc1))
                            val5 = FrmHome.calcArray.Item(FrmHome.calcArray.LastIndexOf(calc1) + 1)
                           val6 = FrmHome.arrayflow(FrmHome.calcArray.LastIndexOf(calc1) + 1)
                            val7 = FrmHome.arrayflow(FrmHome.calcArray.LastIndexOf(calc1) + 2)
                        Else
                        Exit For
                        End If
                        Next


                   FrmHome.result = ((val - val4) * (val7 - val6)) / (val5 - val4)
                    FrmHome.result = FrmHome.result + val6
                Else
                    Dim val13 As Double
                    val13 = FrmHome.arrayflow(val3 + 1)
                    FrmHome.result = val13
                End If
            End If
  FrmHome.resultarray.Add(FrmHome.result)
  DataGridView1.Rows.Add(New String() {i, FrmHome.result.ToString("0.00"), val.ToString("0.0")})
            i = i + 1
            val = val + 5
        Loop
        FrmHome.AvailableFlowDurationValuesToolStripMenuItem.Enabled = True
        availflow()
        FrmHome.FlowDurationCurveToolStripMenuItem.Enabled = True
    End Sub
    Private Sub DataGridView1_CellContentClick(ByVal sender As System.Object, ByVal e As
System.Windows.Forms.DataGridViewCellEventArgs) Handles DataGridView1.CellContentClick
    End Sub
      Private Sub FrmFlowDuration_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        flowduration()
         End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Me.Hide()
End Sub
End Class
```

Plant capacity codes

```
Public Class FrmPlantCapacity
```

```
Private Sub FrmPlantCapacity_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
Dim hhydr As Single
hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
    'for francis turbine
    Dim df As Single
    Dim nqf As Single
    Dim enqf As Single
    Dim edf As Single
    Dim epf As Single
    Dim Qpf As Single
    Dim depf As Single
    Dim erf As Single
    df = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
    nqf = 600 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
    enqf = ((nqf - 56) / 256) ^ 2
    edf = ((0.081 + enqf) * (1 - ((0.789) * (df ^ (-0.2)))))
    epf = (0.919 - enqf + edf) - 0.0305 + (0.05 * 4.5)
    Qpf = 0.65 * FrmHome.desflow * (nqf ^ (0.05))
    depf = 0.007 * (nqf ^ (0.4))
    erf = (1 - depf) * epf
    'for kaplan turbine
    Dim dk As Single
    Dim nqk As Single
    Dim enqk As Single
    Dim edk As Single
    Dim epk As Single
    Dim Qpk As Single
    dk = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
    nqk = 800 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
    enqk = ((nqk - 170) / 700) ^ 2
    edk = ((0.095 + enqk) * (1 - ((0.789) * (dk ^ (-0.2)))))
    epk = (0.905 - enqk + edk) - 0.0305 + (0.05 * 4.5)
    Qpk = 0.75 * FrmHome.desflow
    'propellor turbine
    Dim dp As Single
    Dim nqp As Single
    Dim enqp As Single
    Dim edp As Single
    Dim epp As Single
    Dim Qpp As Single
    dp = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
    nqp = 800 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
    enqp = ((nqk - 170) / 700) ^ 2
    edp = ((0.095 + enqp) * (1 - ((0.789) * (dp ^ (-0.2)))))
    epp = (0.905 - enqp + edp) - 0.0305 + (0.05 * 4.5)
    Qpp = FrmHome.desflow
    'for pelton turbine

    Dim npel As Single
    Dim dpel As Single
    Dim eppel As Single
    Dim Qppel As Single
    npel = 31 * (((FrmHome.grosshead - FrmHome.Lhydrmax) * (FrmHome.desflow / FrmHome.j)) ^ (0.5))
    dpel = (49.4 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (0.5)) * ((FrmHome.j) ^ (0.02))) / npel
    eppel = 0.864 * (dpel ^ (0.04))
    Qppel = (0.662 + (0.001 * FrmHome.j)) * FrmHome.desflow
    'For turgo
    Dim ept As Single
    ept = eppel - 0.03
    'For crossflow
    Dim Qpc As Single
    Qpc = FrmHome.desflow
```

```
        If Frm_Turbine_Type.RadioButton7.Checked = True Then
            'manual plant capacity

 FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) *
(FrmHome.eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
        End If
        'francis plant capacity
        If Frm_Turbine_Type.RadioButton1.Checked = True Then
            Dim eff As Single
            If FrmHome.desflow = Qpf Then
                eff = epf
            ElseIf FrmHome.desflow < Qpf Then
 eff = (1 - (1.25 * (((Qpf - FrmHome.desflow) / Qpf) ^ (3.94 - 0.0195 * nqf)))) * epf
 ElseIf FrmHome.desflow > Qpf Then
 eff = epf - ((((FrmHome.desflow - Qpf) / (FrmHome.desflow - Qpf)) ^ 2) * (epf - erf))
            End If
            FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff)
* FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)


        End If
        'kaplan plant capacity
        If Frm_Turbine_Type.RadioButton2.Checked = True Then
            Dim eff As Single
            If FrmHome.desflow = Qpk Then
                eff = epk
            Else
                eff = (1 - 3.5 * (((Qpk - FrmHome.desflow) / Qpk) ^ 6)) * epk
            End If
            FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff)
* FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
        End If
        'propellor plant capacity
        If Frm_Turbine_Type.RadioButton3.Checked = True Then
            Dim eff As Single
            eff = epp
            FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff)
* FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
       End If
        If Frm_Turbine_Type.RadioButton4.Checked = True Then
            Dim eff As Single
            If FrmHome.desflow = Qppel Then
                eff = eppel
            Else
                eff = (1 - ((1.31 + (0.025 * FrmHome.j)) * (Math.Abs((Qppel - FrmHome.desflow) / Qppel)) ^ (5.6 + (0.4 *
FrmHome.j)))) * eppel
            End If
            FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff)
* FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
       End If
        If Frm_Turbine_Type.RadioButton5.Checked = True Then
            Dim eff As Single
            If FrmHome.desflow = Qppel Then
                eff = ept
            Else
                eff = ((1 - ((1.31 + (0.025 * FrmHome.j)) * (Math.Abs((Qppel - FrmHome.desflow) / Qppel)) ^ (5.6 + (0.4 *
FrmHome.j)))) * eppel) - 0.03
            End If
            FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff)
* FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
       End If
        If Frm_Turbine_Type.RadioButton6.Checked = True Then
            Dim eff As Single
```

```
        eff = 0.79 - 0.15 * ((FrmHome.desflow - FrmHome.desflow) / Qpc) - 1.37 * (((FrmHome.desflow - FrmHome.desflow) / Qpc) ^ 14)
        FrmHome.Pdes = (1000 * 9.81 * FrmHome.desflow) * (FrmHome.grosshead) * (1 - FrmHome.Lhydrmax) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
      End If
      If FrmHome.Pdes = 0 Then
        Label1.Text = "One or some of the parameters needed for this computation has not been entered, go to help for assistance"
      Else
        FrmHome.Pdes = FrmHome.Pdes / 1000
        Label1.Text = "The Plant has the capacity of " & FrmHome.Pdes.ToString("#,###.##") & " " & "kW"
        FrmHome.PowerDurationValuesToolStripMenuItem.Enabled = True
        Frmpowerduration.powerduration()
      End If
    End Sub

    Private Sub Button1_Click(ByVal sender As Object, ByVal e As System.EventArgs) Handles Button1.Click
      Me.Hide()
    End Sub

End Class
```

Power duration codes

```
Public Class Frmpowerduration
    Public Sub powerduration()
      Dim hhydr, htail As Single
      DataGridView1.Rows.Clear()
      Dim c As Integer
      'for francis turbine
      Dim df As Single
      Dim nqf As Single
      Dim enqf As Single
      Dim edf As Single
      Dim epf As Single
      Dim Qpf As Single
      Dim depf As Single
      Dim erf As Single
      df = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
      nqf = 600 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
      enqf = ((nqf - 56) / 256) ^ 2
      edf = ((0.081 + enqf) * (1 - ((0.789) * (df ^ (-0.2)))))
      epf = (0.919 - enqf + edf) - 0.0305 + (0.05 * 4.5)
      Qpf = 0.65 * FrmHome.desflow * (nqf ^ (0.05))
      depf = 0.007 * (nqf ^ (0.4))
      erf = (1 - depf) * epf
      'for kaplan turbine
      Dim dk As Single
      Dim nqk As Single
      Dim enqk As Single
      Dim edk As Single
      Dim epk As Single
      Dim Qpk As Single
      dk = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
      nqk = 800 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
      enqk = ((nqk - 170) / 700) ^ 2
      edk = ((0.095 + enqk) * (1 - ((0.789) * (dk ^ (-0.2)))))
      epk = (0.905 - enqk + edk) - 0.0305 + (0.05 * 4.5)
      Qpk = 0.75 * FrmHome.desflow
      'propellor turbine
      Dim dp As Single
      Dim nqp As Single
      Dim enqp As Single
      Dim edp As Single
```

```
    Dim epp As Single
    Dim Qpp As Single
    dp = ((0.46) * ((FrmHome.desflow) ^ (0.473)))
    nqp = 800 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (-0.5))
    enqp = ((nqk - 170) / 700) ^ 2
    edp = ((0.095 + enqp) * (1 - ((0.789) * (dp ^ (-0.2)))))
    epp = (0.905 - enqp + edp) - 0.0305 + (0.005 * 4.5)
    Qpp = FrmHome.desflow
    'for pelton turbine

    Dim npel As Single
    Dim dpel As Single
    Dim eppel As Single
    Dim Qppel As Single
    npel = 31 * (((FrmHome.grosshead - FrmHome.Lhydrmax) * (FrmHome.desflow / FrmHome.j)) ^ (0.5))
    dpel = (49.4 * ((FrmHome.grosshead - FrmHome.Lhydrmax) ^ (0.5)) * ((FrmHome.j) ^ (0.02))) / npel
    eppel = 0.864 * (dpel ^ (0.04))
    Qppel = (0.662 + (0.001 * FrmHome.j)) * FrmHome.desflow
    'For turgo
    Dim ept As Single
    ept = eppel - 0.03
    'For crossflow
    Dim Qpc As Single
    Qpc = FrmHome.desflow

    If Frm_Turbine_Type.RadioButton7.Checked = True Then
       'manual power duration
       For c = 0 To 20
          If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
             htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
             FrmHome.arrayavailflow(c) = FrmHome.desflow
             hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
          ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
             FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
             hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
             htail = 0
          End If
          FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (FrmHome.eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)

       Next
    End If
    'francis plant capacity
    If Frm_Turbine_Type.RadioButton1.Checked = True Then
       Dim eff As Single
       For c = 0 To 20
          If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
             htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
             FrmHome.arrayavailflow(c) = FrmHome.desflow
             hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
          ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
             FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
             hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
             htail = 0
          End If
          If FrmHome.arrayavailflow(c) = Qpf Then
             eff = epf
          ElseIf FrmHome.arrayavailflow(c) < Qpf Then
             eff = (1 - (1.25 * (((Qpf - FrmHome.arrayavailflow(c)) / Qpf) ^ (3.94 - 0.0195 * nqf)))) * epf
          ElseIf FrmHome.arrayavailflow(c) > Qpf Then
```

```
            eff = epf - ((((FrmHome.arrayavailflow(c) - Qpf) / (FrmHome.desflow - Qpf)) ^ 2) * (epf - erf))
          End If
          FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
        Next

      End If
      'kaplan plant capacity
      If Frm_Turbine_Type.RadioButton2.Checked = True Then
        Dim eff As Single
        For c = 0 To 20
          If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
            htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
            FrmHome.arrayavailflow(c) = FrmHome.desflow
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
          ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
            FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
            htail = 0
          End If
          If FrmHome.arrayavailflow(c) = Qpk Then
            eff = epk
          Else
            eff = (1 - 3.5 * (((Qpk - FrmHome.desflow) / Qpk) ^ 6)) * epk
          End If
          FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)

        Next
      End If
      'propellor plant capacity
      If Frm_Turbine_Type.RadioButton3.Checked = True Then
        Dim eff As Single
        For c = 0 To 20
          If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
            htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
            FrmHome.arrayavailflow(c) = FrmHome.desflow
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
          ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
            FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
            htail = 0
          End If
          If FrmHome.arrayavailflow(c) = Qpp Then
            eff = epp
          Else
            eff = (1 - 1.25 * ((Qpp - FrmHome.arrayavailflow(c)) / Qpp) ^ 1.13) * epp
          End If
          FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
        Next

      End If
      If Frm_Turbine_Type.RadioButton4.Checked = True Then
        Dim eff As Single
        For c = 0 To 20
          If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
            htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
            FrmHome.arrayavailflow(c) = FrmHome.desflow
```

```
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
         ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
            FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
            htail = 0
         End If
         If FrmHome.desflow = Qppel Then
            eff = eppel
         Else
            eff = (1 - ((1.31 + (0.025 * FrmHome.j)) * (Math.Abs((Qppel - FrmHome.desflow) / Qppel)) ^ (5.6 + (0.4 *
FrmHome.j)))) * eppel
         End If
         FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
      Next

   End If
   If Frm_Turbine_Type.RadioButton5.Checked = True Then
      Dim eff As Single
      For c = 0 To 20
         If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
            htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
            FrmHome.arrayavailflow(c) = FrmHome.desflow
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
         ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
            FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
            htail = 0
         End If
         If FrmHome.desflow = Qppel Then
            eff = ept
         Else
            eff = ((1 - ((1.31 + (0.025 * FrmHome.j)) * (Math.Abs((Qppel - FrmHome.desflow) / Qppel)) ^ (5.6 + (0.4 *
FrmHome.j)))) * eppel) - 0.03
         End If
         FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
      Next

   End If
   If Frm_Turbine_Type.RadioButton6.Checked = True Then
      Dim eff As Single
      For c = 0 To 20
         If FrmHome.arrayavailflow(c) > FrmHome.desflow Then
            htail = FrmHome.Htailmax * (((FrmHome.resultarray.Item(c) - FrmHome.desflow) ^ 2) /
((FrmHome.arrayflow(0) - FrmHome.desflow) ^ 2))
            FrmHome.arrayavailflow(c) = FrmHome.desflow
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * (FrmHome.desflow ^ 2 / FrmHome.desflow ^ 2)
         ElseIf FrmHome.arrayavailflow(c) < FrmHome.desflow Then
            FrmHome.arrayavailflow(c) = FrmHome.arrayavailflow(c)
            hhydr = FrmHome.grosshead * FrmHome.Lhydrmax * ((FrmHome.arrayavailflow(c)) ^ 2 /
FrmHome.desflow ^ 2)
            htail = 0
         End If
         eff = 0.79 - 0.15 * ((FrmHome.desflow - FrmHome.desflow) / Qpc) - 1.37 * (((FrmHome.desflow -
FrmHome.desflow) / Qpc) ^ 14)
         FrmHome.pduration(c) = (1000 * 9.81 * FrmHome.arrayavailflow(c)) * ((FrmHome.grosshead) - (hhydr +
htail)) * (eff) * FrmHome.Eg * (1 - FrmHome.Ltrans) * (1 - FrmHome.Lpara)
      Next

   End If
```

```
        'populating the datagrid
        Dim d, value As Integer
        d = 0
        value = 0
        Do While (d <= 20)
            FrmHome.pduration(d) = FrmHome.pduration(d) / 1000
            DataGridView1.Rows.Add(New String() {(d + 1), FrmHome.pduration(d).ToString("#,###.##"), value})
            d += 1
            value += 5
        Loop
        FrmHome.PowerDurationCurveToolStripMenuItem.Enabled = True
        FrmHome.RenewableEnergyAvailableToolStripMenuItem.Enabled = True
    End Sub

    Private Sub Frmpowerduration_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles
MyBase.Load
        If FrmHome.arrayavailflow(0) = 0 Then
            Dim result As DialogResult = MessageBox.Show("Power duration can not be computed because flow values have
not been loaded. Do you want to load flow data?", _
                                                         "Unable to compute power duration", MessageBoxButtons.YesNo,
MessageBoxIcon.Question, MessageBoxDefaultButton.Button1)
            If result = DialogResult.Yes Then
                Me.Close()
                FrmFlow.ShowDialog()
            ElseIf result = DialogResult.No Then
                Me.Close()
            End If
        Else
            powerduration()
        End If
    End Sub

    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
        Me.Hide()
    End Sub

End Class
```

Renewable energy available codes

```
Public Class FrmRenEnergy

    Private Sub RenEnergy_Load(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles MyBase.Load
        If FrmHome.arrayavailflow(0) = 0 Then
            Dim result As DialogResult = MessageBox.Show("Renewable energy available can not be computed because
flow values have not been loaded. Do you want to load flow data?", _
                                                         "Unable to compute Renewable energy available", MessageBoxButtons.YesNo,
MessageBoxIcon.Question, MessageBoxDefaultButton.Button1)
            If result = DialogResult.Yes Then
                Me.Close()
                FrmFlow.ShowDialog()
            ElseIf result = DialogResult.No Then
                Me.Close()
            End If
        Else
            Dim k As Integer
            Dim Db, Dd, Dc As Double
            k = 0
            Db = 0
            Do While (k <= 19)
                Dd = ((FrmHome.pduration(k) + (FrmHome.pduration(k + 1))) / 2) * (5 / 100) * 8760 * (1 - FrmHome.Ldt)
                Dc = Dd + Db
                Db = Dc
                k += 1
            Loop
```

```
        FrmHome.RenEnergy = Db
        Db = Db / 1000
        Label1.Text = ("The Renewable Energy Available is " & Db.ToString("#,###.##") & " kWh/yr")
      End If
    End Sub
    Private Sub Button1_Click(ByVal sender As System.Object, ByVal e As System.EventArgs) Handles Button1.Click
      Me.Hide()
    End Sub
End Class
```