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# Gas-To-Plant Installation Analysis Using Well Performance Data

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## ABSTRACT

**Gas-to-Plant is a system of transportation of natural gas in which gases from wellheads are delivered directly to the power plant for power generation without passing through the flow station or any gas gathering/treatment plant. The study utilized data from 88 General Electric gas turbines and 64 SIEMENS gas turbines as provided by the Manufacturing companies. Well data were collected and a model for determining the fuel requirement of gas turbines based on specific parameters was developed. Models for determining the quantity of electricity that can be generated based on any given well performance information were also developed for both Combined Cycle and Simple Cycle gas turbine types. A computer application software "Falcon" that allows for quality installation analysis, and accurate selection of gas turbines for power generation was developed. The software utilized the developed models from this study and decline equations from literature, inheriting a power output prediction absolute error margin of 3% and 5% for Simple Cycle and Combined Cycle gas turbines respectively. The deviation was large because the data were obtained from different gas turbine manufacturers. The study results suggest the exact type(s) of gas turbine power plant that will generate a required quantity of electricity over the estimated remaining life of the given well. This study shows that, if properly conditioned, single wells can be used for the generation of electricity via a gas-to-plant technique.**

## 1. Introduction

The usage of Natural gas for power generation dates back to the 1900s, stimulated by the low natural gas prices at that time. Electricity generated using natural gas turbines was first produced for public use in 1939/1940 at a plant in Neuchâtel, Switzerland with a total turbine output of 4 megawatts (MW). In 1960, North America installed a Power Plant in Port Mann, British Columbia and became the largest gas plant in the world, operating with a 100 MW capacity. A year later in 1961, the first combined-cycle plant began operation in Korneuburg, Austria. It generated 75 MW of electricity (Miser, 2015). In 2003, natural gas passed coal as the energy source with the largest installed electricity generation capacity in the United States (Uses of Natural Gas, 2015). Natural gas-fired Plants are currently among the cheapest power plants to construct. The open cycle gas turbine operates on the principle of drawing the fresh atmospheric air at ambient conditions into the compressor where the air

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is compressed by a centrifugal or an axial flow compressor (Adefarati and Bansal, 2019). A closed-cycle gas turbine can be defined as a gas turbine, which overcomes the drawbacks of the open cycle gas turbine (Bethel *et al.,* 2018). In this type of turbine, the air is circulated continuously within the gas turbine with the help of a compressor, heat chamber, gas turbine, and cooling chamber. The ratios of pressure, temperature, and air velocities will be constant in this type. It performs a thermodynamic cycle, which means working fluid is circulated and used continuously again and again without leaving the system (Elprocus, 2018). The basic difference between them is the circulation of the working fluid. In the closed cycle gas turbine, the same working fluid is circulated again and again within the turbine but in the open cycle gas turbine the working fluid i.e. air is replaced again and again while flowing through the gas turbine (Mishra, 2016). They also have very high thermodynamic efficiencies compared to other power plants. Burning of natural gas produces fewer pollutants like NOx, SOx and particulate matter than coal and oil (Bethel *et al.,* 2019). Gas turbines can operate with a wide range of fuel types. This may include: ‘Pipeline’ quality Natural Gas fuels, Premium liquid fuels, Liquified Natural Gas (LNG), Unconventional Gaseous Fuels (Coal Bed Methane/Shale), Biogas fuels, Natural Gas Liquids and LPG fuels, Refinery; Process Off-gas; Hydrogen Syngas, Crude Oil, Wellhead Gases. (Welch and Igoe, 2015). On the other hand, well-head gas is natural gas fuel located near the upstream oil and gas production facilities or gas that is flowed through pipes that have never undergone a regasification process (Persero, 2019). Electricity generation at or near the reservoir source and transportation by cable to the destination(s) (gas-to-power, GTP) is possible. According to Oddmar *et al.* (2018), natural gas power plants have high efficiencies and correspondingly low CO2 emissions compared to other fossil fuels. This distinctive feature of natural gas has made it to be widely accepted as a clean energy alternative to other fossil fuels. Based on a study conducted in Indonesia, as engine power plant with gas from the well head gas has an electricity tariff of IDR 1,262.21 per KWh cheaper than the selling value of Perusahaan Listrik Negara (PLN) electricity of IDR 1,467.28 per KWh, for a gas engine power plant with gas fuel from the well head gas has a better economic value with an IRR of 24.78% and payback period of 4.88 years so that the gas engine power plant with gas from the wellhead can be a consideration for the policy of selecting the construction of gas fired power plants in Aceh province (Budiana and Dalimi, 2021). Nevertheless, gas-to-power has been an option much considered in the US for getting energy from the Alaskan gas and oil fields to the populated areas. (Speight, 2019)

In Nigeria, the oil and gas industry operations often face complex human rights-related issues. Among other things, the cravings of these communities include a stable electricity. The communities of most oil and gas fields in Nigeria have long depended on the national power grid for the supply of electricity which in time past have only provided an epileptic supply of power to these environments and the nation at large. This work intends to provide field managers a system for evaluating various gas wells in their fields, most especially non-associated gas (NAG) wells, with the aim to select at least one well that is cost efficient to run a gas power plant that will generate a maximum power output that can supply adequate electricity over the remaining life of the selected well with or without support (electricity supply) from the national power grid. This study developed a computer application that allows the oil and gas field manager to easily select a gas turbine power plant, given the performance data of the wells in the field. The study uses decline curve analysis to determine the production life of given well(s) at different flow rates and developed mathematical models that can determine turbine fuel gas injection rate; and vary power output to fuel injection rate.

## 1. Methodology

This study was carried out on well 3S, 15T, 30S, 21T, 11T, and 5S in XYZ and BMX onshore oil and gas field located in Niger Delta region of Nigeria. Well A, a gas field in West Virginia, US. Wells B, and C, are gas wells in Texas-Eagle Ford Shale. The remainng lives of the wells XYZ and BMX fields were assumed because the volume of the recoverable hydrocarbon in the wells were not given. However, Wells A, B, and C are of known volumes; 3360 MMSCF, 5000 MMSCF, and 10000 MMSCF respectively. The Falcon software was designed using Python programing language, PyCharm IDE interpreter, PyQt5 Graphic User Interface (GUI) designer, and Microsoft Excel. The python programing libraries used in the software design include: Python Pandas, Numpy, Openpyxl.

### 2.1 Data Gathering Description

Gas Turbines data were obtained from two gas turbine manufacturers, General Electric and SIEMENS. Data gotten include: Gas Turbine Types, Net Heating Rate, Power Output (MW), Efficiency and Frequency. Turbine fuel consumption mathematical model was derived as shown in equation 1 to 5. The average life span of the gas turbines was determined by spreading the average life span estimation of gas turbines as detailed by Duquiantan, 2019 over 150 simple gas (SC) and combine cycle (CC) gas turbines. Given the cost per KW unit of gas turbines from the 2018 capital expenditure (CAPEX) forecast, report and summary of Annual Technology Baseline (ATB), the cost of turbines 150 gas turbines was calculated (using equation 6 & 7), both CC and SC Turbines (64 SIEMENS and 88 General Electric). In addition, the number of households per KW electricity was based on a 2010 study in the US by Wilson, 2015; that infers that a household consumes about 1.3356 KW electricity per time (this was calculated from equation 8). The mathematical models equations 9 to 10 were developed by method of regression. Equations 11 to 13 are decline equations for production forecast. The gas turbine data and the study developed computer software "Falcon" application algorithms is presented in appendix A, B1 to B3, respectively. The mathematical equations used in this study are expressed below:

#### 2.1.1 Fuel Consumption

Parameters:

Net Heating Rate = NHR (Btu/KWh)

Thermal unit = TU (Btu/d)

Power Output = Output (MW)

Consumption = Q (MMSCF/D)

$$TU\left(\frac{Btu}{d}\right) = \left[NHR\left(\frac{Btu}{KWh}\right) x\ Output\ (KW)\ x\ 24\right]\left(\frac{Btu}{d}\right) \qquad (1)$$

Given that:

1 mmscf/d = 1040 mmBtu/d

Q mmscf/d = TU

$$Q = \frac{TU\left(\frac{Btu}{d}\right) x\ 1\left(\frac{mmscf}{d}\right)}{1040\ x\ 10^{6}\left(\frac{Btu}{d}\right)} \qquad (2)$$

$$Q = \frac{\left[NHR\left(\frac{Btu}{KWh}\right) x\ Output\ (KW)\ x\ 24\right]\left(\frac{Btu}{d}\right) x\ 1\left(\frac{mmscf}{d}\right)}{1040\ x\ 10^{6}\left(\frac{Btu}{d}\right)} \qquad (3)$$

$$Q = \left[\frac{NHR\left(\frac{Btu}{KWh}\right) x\ Output\ (MW)\ x\ 24\ x\ 1000}{1040\ x\ 10^6}\right]\left(\frac{mmscf}{d}\right)$$

(4)

$$Q = \left[\frac{NHR\left(\frac{Btu}{KWh}\right) x\ Output\ (MW)\ x\ 24}{1040\ x\ 10^3}\right]\left(\frac{mmscf}{d}\right)$$

(5)

### 2.1.2 Cost of Turbine

Cost per unit of Simple Cycle gas Turbine = $P_{SC}$

Power Output of Simple Cycle gas Turbine = $Output_{SC}$ (KW)

Cost per unit of Combine Cycle gas Turbine = $P_{CC}$

Power Output of Combined Cycle gas Turbine = $Output_{CC}$ (KW)

**i. Simple Cycle Gas Turbine:**

$$P_{SC} = Output_{SC}(KW)\ x\ \$969$$

(6)

ii. **Combine Cycle Gas Turbine:**

$$P_{CC} = Output_{CC}(KW)\ x\ \$1{,}050$$

(7)

### 2.1.3 Number of House Hold

$$N = \frac{Output\ (KW)}{1.3356(KW)}$$

(8)

### 2.1.4 Power Output

q = Well flowrate (mmscf/d) (turbine feed rate)

P = Power output (MW)

**i. Simple Cycle**

$$P = 4.2109(q)^{1.0573}$$

(9)

**ii. Combined Cycle**

$$P = 5.8006(q)^{1.0685}$$

(10)

### 2.1.5 Decline Curve Equations

tf = well life (days)

qo = initial flow rate (mmscf/d)

qf = Abandonment rate (mmscf/d)

Npd = Recoverable reserve

**i. Exponential Decline**

$$tf = \frac{N_{pd}}{q_o}\ln\left(\frac{q_o}{q_f}\right)$$

(11)

**ii. General Hyperbolic Decline**

$$tf = \frac{N_{pd}}{q_o}\sqrt{\frac{q_o}{q_f}}$$

(12)

**iii. Harmonic Decline**

$$tf = \frac{N_{pd}}{q_o}\left(\frac{\left(\frac{q_o}{q_f}-1\right)}{\ln\left(\frac{q_o}{q_o}\right)}\right)$$

(13)

### 2.2 Well Head Gas-to-Power Plant Design Layout

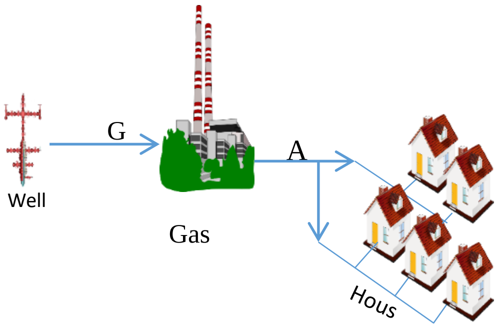


**Figure 1:** Flow process from Wellhead to Power plant and electricity to Houses

### 2.2 Description of the Falcon Software

Among others things, the Falcon system application is designed basically to perform three functions:

1. To help oil and gas field management know if one or more wells in a partic-

ular field is suitable for power generation, based on the existing power generation technology. And if available, to know the cost of the turbine, and the power rating of the turbine.

2. To help validate if an intended gas turbine, with known power rating, is compatible with at least one gas well in a field.
3. To estimate the quantity of electricity a given well can generate throughout the remaining life of the well if produced at different rates.

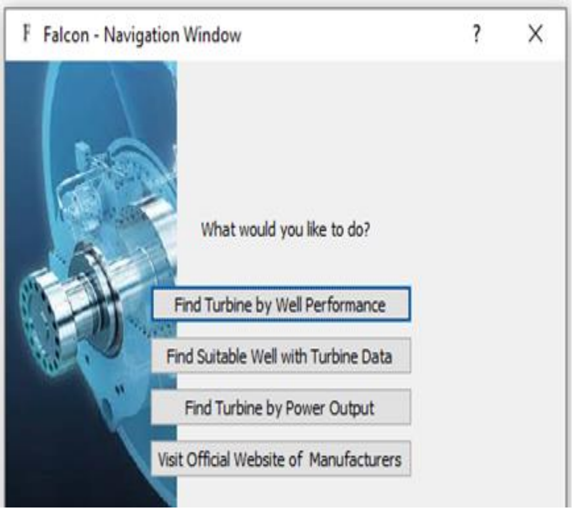
However, these the software shall do via the mathematical models and various loop codes running in the background of the software. When started, the application opens with a welcome window (Plate 1) showing the name of the of the application software, a fun fact that gives a concise function of the software which also tells the riddle of why the application was given the name. Also, displayed in the welcome window is a button that links to the navigation window.

Did you know?
Falcons are fast--really fast; and have really sharp eyes that can see more detail than the human eye. Yes, exactly what I will be doing for you in Gas Turbine selection--speed and accuracy.

**Plate 1**: Falcon Welcome Window

The navigation window (Plate 2) consists of four buttons linking to the windows that perform various functions depending on the need of the user. The buttons are:

- Find Turbine by Well Data
- Find suitable Well with Turbine Data
- Find Turbine by Output
- Visit official Website of Manufacturers



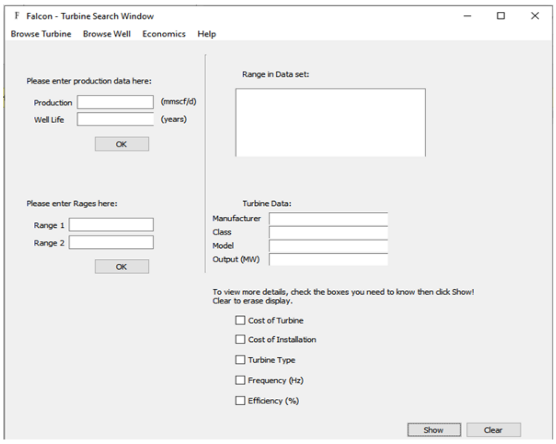
What would you like to do?

**Plate 2**: Falcon Navigation Window

The description of the first and second interface will be discussed as they form the foundation of this work.

### 2.2.1 Find Turbine by Well Data

Say, there exists a well with known flowrate and life span. To know if a gas turbine exists that will require exactly the volume of gas produced by the well per day as feed for the approximated life span of the gas Turbine, "Find Turbine by Well Data" button shall be clicked. This button, when clicked, leads to a window titled, "Falcon - Turbine Search" (Plate 3).



To view more details, check the boxes you need to know then click Show!
Clear to erase display.

**Plate 3:** Falcon Turbine Search Window

This window gives user an interface to find gas turbine with an available well performance information (lifespan and flowrate).

Below is the list of the content of the interface:

1. Production rate input box
2. Well life input box
3. Range graphic display box
4. Ranges input boxes
5. Basic Turbine data graphic display box
6. “Cost of Turbine” Checkbox
7. “Cost of Installation” Checkbox
8. “Turbine Type” Checkbox
9. “Frequency” Checkbox
10. “Efficiency (Hz)” Checkbox
11. “OK”, “Show” and “Clear” buttons

The production rate input box takes the value of the flowrate of the well in million standard cubic foot per day (MMSCF/D). The Well life input box takes the value of the well life. When the “OK” button is clicked, the Turbine range graphic display box shows the exact fuel consumption rate and the ranges of the turbine(s) whose requirement for operation is consistent with the imputed well data. Given that multiple turbines are displayed in the Range graphic display box, the Range input boxes take the ranges of the particular turbine of the user’s choosing. When the “OK” button is clicked, the Basic Turbine data graphic display boxes show a concise detail of the selected turbine. Detail include only: Turbine Manufacture, Turbine Class, Turbine Model, Turbine Power Output. However, depending on the information the user choses to retrieve, any of “Cost of Turbine”, “Cost of Installation”, “Turbine Type”, “Frequency (Hz)”, “Efficiency (%)” check boxes may be checked and when “Show” button is clicked, the application displays the information of the Gas Turbine by the boxes. The “Clear” button clears the newly displayed information. A flow chat of the application is shown appendix B2.

### 2.2.2 Find Suitable Well with Turbine Data

Given a data consisting of the flowrate of wells in a certain field. To know if there exists a well in the field which meets the basic requirement of the available Gas Turbine, this option is selected. This button, when clicked, leads to a window titled, “Falcon - Well Search” (Plate 4).

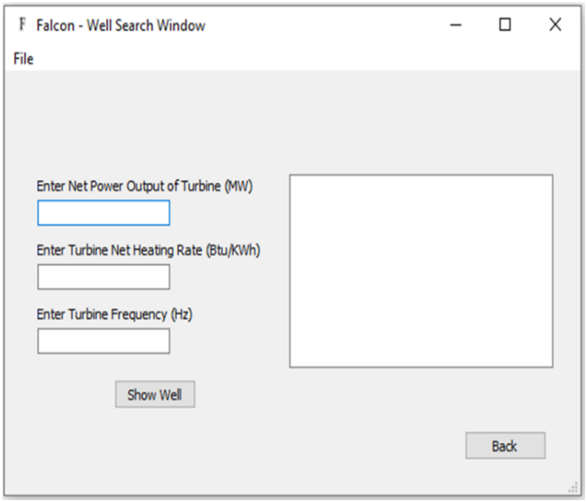


**Plate 4:** Falcon Well Search Window

This window gives user an interface that allows to find Well(s) (in a field) that is suitable to operate a selected or proposed gas turbine.

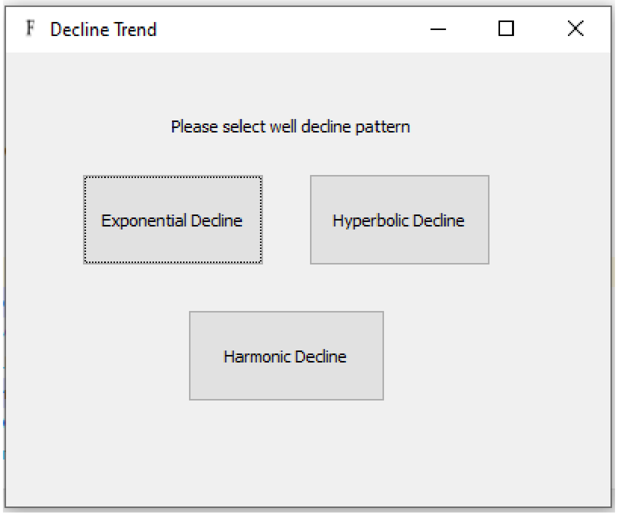
Below is a list of the content of the window:

1. Turbine Net Power input box
2. Turbine Net Heating rate input box
3. Turbine Frequency Input box
4. File – Upload Field data
5. Suggestion display box
6. “Show Well” and “Back” buttons

The Turbine Net Power Input box takes the Power Output of the turbine in Megawatt (MW). The Turbine Net Heating Rate Input box takes the value of the Net Heating rate of the Gas Turbine in British thermal unit per kilowatt-hour (Btu/KWh). The Turbine Frequency Input box takes the frequency of the Gas Turbine. The Upload Field data button allows user to upload field well data. When the “Show Well” button is clicked, the system displays the best fit well in the field in the Suggestion display box. The “Back button” returns the user to the “Navigation Window”. A flow chat of the application is shown appendix B3.

### 2.2.3 Find Turbine by Power

This button, when clicked, leads to a window titled, “Decline Trend” (Plate 5).

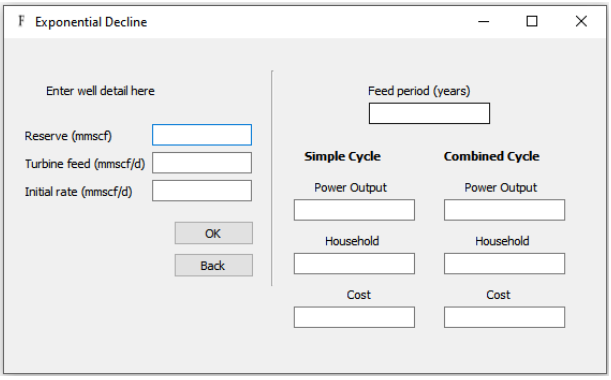


Decline Trend

Please select well decline pattern

**Plate 5:** Decline Trend selection Window

This window displays a selection interface which can allow user to select the type of decline trend he wishes to run (either Hyperbolic, Harmonic or Exponential). The Exponential Decline window (Plate 6) allows to evaluate a well and determine the quantity of electricity it can generate, cost and the maximum number of households it can supply electricity per time.



Exponential Decline

Enter well detail here

**Plate 6:** Falcon Power Output Window for Exponentially Declining Well

The content of the window is listed below.

1. Reserve impute box
2. Turbine feed rate box
3. Initial rate input box
4. Feed Period Display box

## 2. Result and Discussion

### 3.1 Results

5. SC Cycle Power Output display box
6. SC Household display box
7. SC Cost display box
8. CC Cycle Power Output display box
9. CC Household display box
10. CC Cost display box
11. A “OK” button and “Back Button”

**Table 1:** Result from Turbine Search Window

| **Name of Well** | **Flow rate (mmscf/d)** | **Life of well (years)** | **Turbine Manufacturer** | **Model** | **Output (MW)** | **Cost of Turbine (US$/unit)** | **Household** |
|---|---|---|---|---|---|---|---|
| 3S | 1.31599 | 30 | SIEMENS | SGT-600 | 5.05 | 4,893,450 | 3781 |
| 15T | 4.94498 | 22 | General Electric | LM2500DLE | 32.8 | 34,440,000 | 24558 |
| 30S | 2.03431 | 32 | SIEMENS | SGT-300 | 7.9 | 7,655,100 | 5914 |
| 21T | 5.47963 | 26 | General Electric | SGT-300 | 34.2 | 35,910,000 | 25606 |
| 11T | 3.18347 | 34 | SIEMENS | SGT-400(C) | 14.3 | 13,856,700 | 10706 |
| 5S | 1.06188 | 27 | SIEMENS | SGT-A05 (KB5S) | 4.0 | 3,876,000 | 2994 |

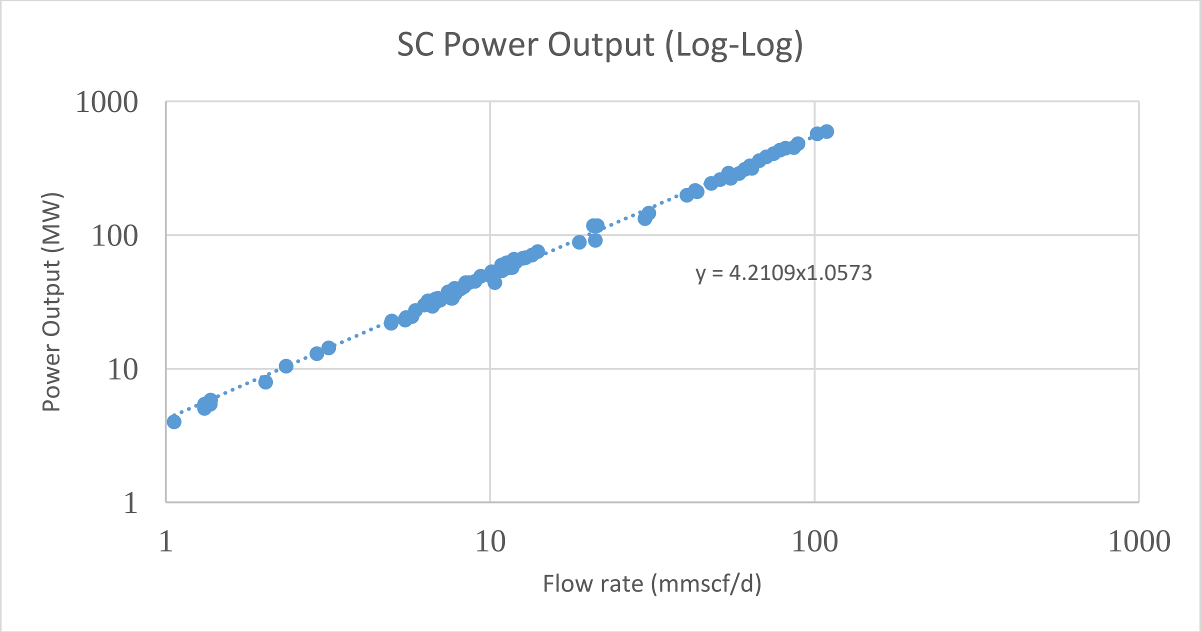


**Figure 2:** Graph of Power output against flowrate for SC Turbine

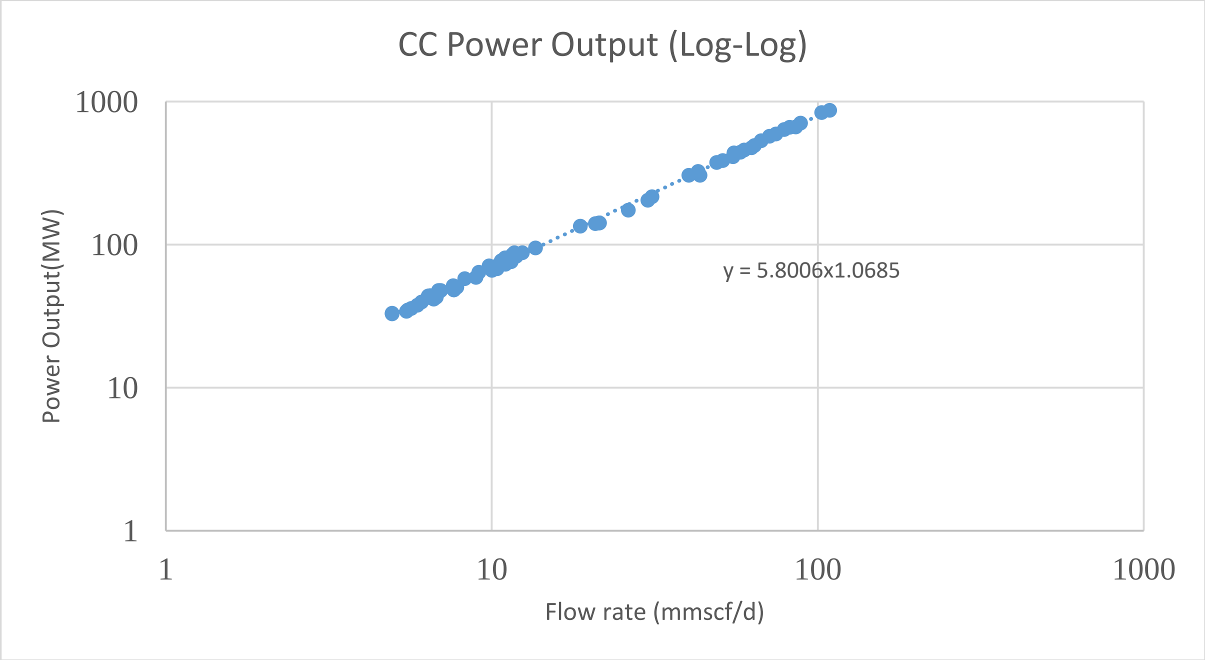


**Figure 3:** Graph of Power output against flowrate for CC Turbine

**Table 2:** Result from Exponential Decline Window for Well A (3,360mmscf)

| **Flow Rate (mmscf/d)** | | | **Simple Cycle Turbine** | | | **Combined Cycle Turbine** | | |
|---|---|---|---|---|---|---|---|---|
| **Initial** | **Turbine Feed** | **Feed Period (years)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** |
| 4.5 | 4 | 2.168 | 18.24 | 13,654 | 17,670,821 | 25.51 | 19,103 | 26,789,420 |
| 3.5 | 3 | 2.838 | 13.45 | 10.073 | 13,036,440 | 18.76 | 14,048 | 19,700,002 |
| 2.5 | 2 | 4.108 | 8.76 | 6,561 | 8,491,369 | 12.17 | 9,109 | 12,773,584 |
| 2 | 1.5 | 5.297 | 6.46 | 4,840 | 6,264,407 | 8.95 | 6,698 | 9,393,247 |
| 1.5 | 1.0 | 7.465 | 4.21 | 3,153 | 4,080,362 | 5.8 | 4,343 | 6,090,630 |

**Table 3:** Result from Exponential Decline Window for Well C (5,000mmscf)

| **Flow Rate (mmscf/d)** | | | **Simple Cycle Turbine** | | | **Combined Cycle Turbine** | | |
|---|---|---|---|---|---|---|---|---|
| **Initial** | **Turbine Feed** | **Feed Period (years)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** |
| 4.5 | 4 | 3.227 | 18.24 | 13,654 | 17,670,821 | 25.51 | 19,103 | 26,789,420 |
| 3.5 | 3 | 4.223 | 13.45 | 10.073 | 13,036,440 | 18.76 | 14,048 | 19,700,002 |
| 2.5 | 2 | 6.114 | 8.76 | 6,561 | 8,491,369 | 12.17 | 9,109 | 12,773,584 |
| 2 | 1.5 | 7.882 | 6.46 | 4,840 | 6,264,407 | 8.95 | 6,698 | 9,393,247 |
| 1.5 | 1.0 | 11.109 | 4.21 | 3,153 | 4,080,362 | 5.8 | 4,343 | 6,090,630 |

**Table 4:** Result from Exponential Decline Window for Well C (10,000mmscf)

| **Flow Rate (mmscf/d)** | | | **Simple Cycle Turbine** | | | **Combined Cycle Turbine** | | |
|---|---|---|---|---|---|---|---|---|
| **Initial** | **Turbine Feed** | **Feed Period (years)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** | **Power Output (MW)** | **Household** | **Cost (US$/unit)** |
| 4.5 | 4 | 6.454 | 18.24 | 13,654 | 17,670,821 | 25.51 | 19,103 | 26,789,420 |
| 3.5 | 3 | 8.447 | 13.45 | 10.073 | 13,036,440 | 18.76 | 14,048 | 19,700,002 |
| 2.5 | 2 | 12.227 | 8.76 | 6,561 | 8,491,369 | 12.17 | 9,109 | 12,773,584 |
| 2 | 1.5 | 15.763 | 6.46 | 4,840 | 6,264,407 | 8.95 | 6,698 | 9,393,247 |
| 1.5 | 1.0 | 22.217 | 4.21 | 3,153 | 4,080,362 | 5.8 | 4,343 | 6,090,630 |

## 3.2 Discussion

Table 1 shows the result of 6 wells from different fields highlighting the basic specifications of the existing gas turbine the wells can successfully feed for the remaining life of the wells if they are produced at the specific rates. The table also shows the number of households each turbine can serve at any given time within its lifetime.

Figure 2 shows a log-log plot of Power output (MW) against Gas injections rate (Well flow rate) for Simple Cycle Turbine types. Figure 3 as well shows a log-log plot of power output (MW) against Gas injections rate (Well flow rate) for Combined Cycle Turbine types.

Table 2 shows the result of well A, having a 3,360 MMSCF of gas reserve. The table highlights the initial flowrate to produce the [given] well, the economic limit (minimum flowrate) which is also equal to the Turbine type gas requirement for power generation, the life of the well (if commissioned for power generation at those rates). The table also shows the power output, cost and the number of households the turbines can supply electricity at any given time for both Simple Cycle Gas Turbine and Combine Cycle Gas Turbine.

Table 3 shows the result of well B, having a 5,000 MMSCF of gas reserve. The table highlights the initial flowrate to produce the well, the economic limit which is also equal to the turbine gas requirement for power generation, the life of the well (if commissioned for power generation at those rates). The table also shows the power output, cost and the number of households the Turbines can supply electricity at any given time for both Simple Cycle Gas Turbine and Combine Cycle Gas Turbine.

Table 4 shows the result of well C, having a 10,000 MMSCF of gas reserve. The table highlights the initial flowrate to produce the well, the economic limit which is also equal to the turbine gas requirement for power generation, the life of the well (if commissioned for power generation at those rates). The table also shows the power output, cost and the number of households the Turbines can supply electricity at any given time for both Simple Cycle Gas Turbine and Combine Cycle Gas Turbine. The results in Table 2 to Table 4 also show that at a given well production rate, the quantity of electricity generated by a Combined Cycle Gas Turbine is higher than its Simple Cycle type, however, slightly at a higher Cost.

Among Well A, B and C, well C shows a longer sustainability of the Power generation at a given well production rate for any given Turbine because of the volume of its reserve base. That is, the larger the volume of gas recoverable from the well (reserve) the longer the well can serve as feed source for that particular Gas turbine.

## 4. Conclusion and Recommendations

### 4.1 Conclusion

The Falcon software was used to determine the quantity of electricity different gas wells can generate at any given initial production rate to a set economic rate, if a gas power plant is installed. Also, the study shows the approximate cost of the turbine types (SCGT and CCGT); and the average number of households the turbines can serve per time. Based on the result gotten from this study, it is therefore established that a single gas well may be sufficient for generating the quantity of electricity required to power a number of households (consumers) throughout the extended (remaining) life of the well. If any well on a field is proven fit, it may therefore be commissioned for power supply to the community as a means of good-will at an efficient cost. Other than the rapport the implementation of this work will create, it may also serve as a means of revenue for the operating company. The implementation of the project in real life scenario may be subjected to the law and regulation of the government, the capacity of the operating company, and the availability of viable well in the operating field. In addition, the software is limited to the available data on which it was built. However, subsequent versions of the software will allow for multiple imputation of well data, more backend gas turbine data set and the deviation incurred in the models due to limited and different turbine manufactures will be reduced to zero.

## 4.2 Recommendation

It is recommended that further study should factor in the possibility of a rising number of households because of infrastructural development. Hence, if the design speculates a certain number of households over an extended period of time for stable electricity supply, then the possibility of a rapid increase in the rate of migration to the feed environment should be factored into the selection and installation plan. Also, the Falcon software should be optimized to capture more turbine data points. More so, the cost of installation (set up) of turbine should be considered in further studies as this study only accounts for the cost of turbine per unit. In addition, the developed models, equations 9 and 10, have absolute error of about 5% and 3% respectively. This should be factored into the installation analysis and turbine design. However, further review may be done to optimise the equations to reduce the prediction error to as low as possible, say, less than 1%. Further study may consider the application of the Falcon software not only for Gas-to-Plant technique but also Flare-to-Plant.

## REFERENCES

[1] Adefarati, T., & Bansal, R. (2019). Energizing Renewable Energy Systems and Distribution Generation. *Pathways to a Smarter Power System*.

[2] Bethel, A., Jordan, H., James, J., Kailyn, S., & Donev, J. (2019). *Natural gas power plant*. Retrieved from Energy Education: www.energyeducation.ca/encyclopedia/Natural_gas_power_plant

[3] Bethel, A., Jordan, H., Kailyn, S., & Donev, J. (2018). *Combined cycle gas plant*. Retrieved from Energy Education: www.energyeducation.ca/encyclopedia/Combined_cycle_gas_plant

[4] Budiana, D., & Dalimi, D. (2021). The Economics Comparison of Power Plants fueled by Wellhead gas and LIquified natural gas in Aceh Province. *Indonesia in their economic analysis*.

[5] Duquiantan, A. (2019). *Average age of US power plant fleet flat for 4th-straight year in 2018*. Retrieved from S&P Global Market Intelligence: https://www.spglobal.com/marketintelligence/en/news-insights/trending/gfjqeFt8GTPYNK4WX57z9g2#:~:text=16%20Jan%2C%202019-,Average%20age%20of%20US%20power%20plant%20fleet,4th%2Dstraight%20year%20in%202018&text=The%20capacity%2Dweighted%20average%20age,four

[6] Elprocus. (2018). *What is a closed cycle Gas Turbine & its working*. Retrieved from Elprocus: www.wlprocus.com/what-is-a-closed-cycle-gas-turbine-its-working

[7] Miser, T. (2015). *A Short History of the Evolving Uses of Natural Gas*. Retrieved from Power Engineering: https://www.power-eng.com/coal/a-short-history-of-the-evolving-uses-of-natural-gas/#gref

[8] Mishra, P. (2016). *Difference Between Closed Cycle Gas Turbine and Open Cycle Gas Turbine*. Retrieved from Mechanical Booster: www.mechanicalbooster.com/2016/06/di

fferece-between-closed-cycle-gas-turbine-and-open-cycle-gas-turbine

[9] Oddmar, E., Eivind, B., & Steven, J. (2018). Optimization of Pure-Component LNG Cascade Processes with Heat Integration. *Energies, 202*(11). doi:10.3390/en11010202

[10] Persero, P. P. (2019). Electric Power Supply Business Plan (2019-2028).

[11] Speight, J. G. (2019). *Natural Gas (Second Edition).*

[12] *Uses of Natural Gas*. (2015). Retrieved from Union of Concerned Scientists: https://www.ucsusa.org/resources/uses-natural-gas

[13] Welch, M., & Igoe, B. (2015). Combustion, Fuels and Emissions for Industrial Gas Turbines. *3rd Middle East Turbomachinery Symposium (METS III).* Doha, Qatar.

[14] Wilson, L. (2015). *Average household electricity use around the world*. Retrieved from Shrink That Footprint: www.shrinkthatfootprint.com/average-household-electricity-consumption

# Appendices

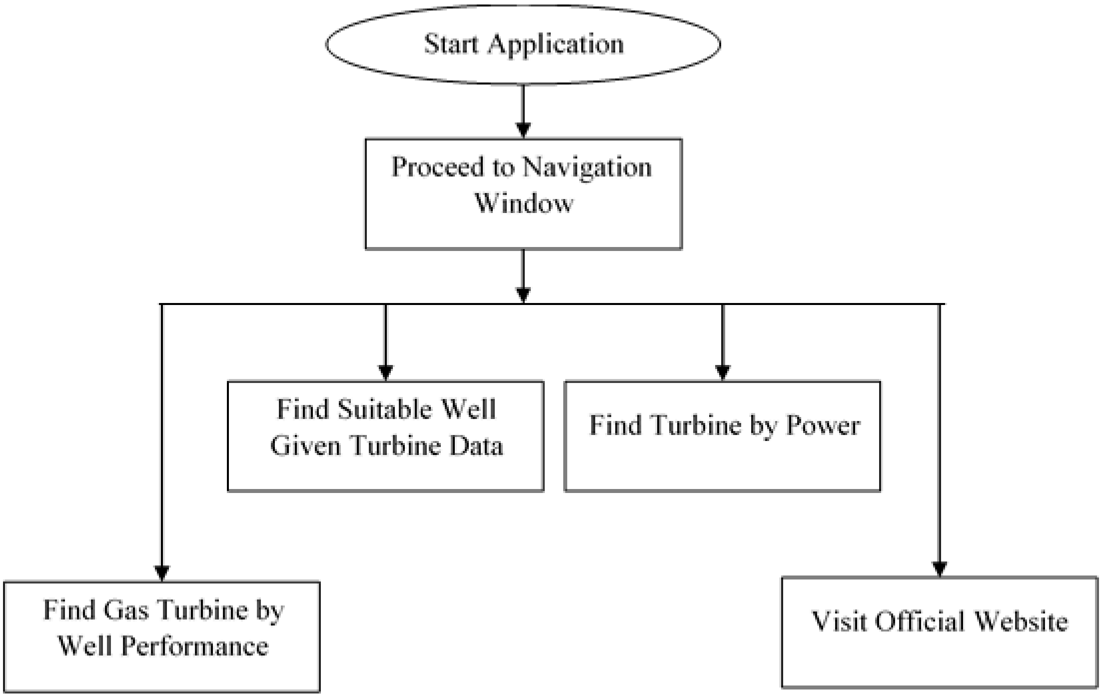
## **Appendix A:** Gas Turbine Data

| SN | Manufacturer | Class | Turbine Type | Model | Net Power Output (MW) | Efficiency (%) | SC Net Heat Rate (Btu/kWh, LHV) | Frequency | Fuel consumption per day (mmscf/d) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | GE | B | SC Plant | 6B.03 | 44 | 33.5 | 10,180 | 50/60 Hz (Geared) | 10.33662 |
| 2 | GE | B | CC Plant | 6B.03 | 68 | 51.6 | 6614 | 50/60 Hz (Geared) | 10.37889 |
| 3 | GE | E | SC Plant | 9E.03 | 132 | 34.6 | 9,860 | 50 | 30.03508 |
| 4 | GE | E | SC Plant | 9E.04 | 145 | 37 | 9,210 | 50 | 30.81808 |
| 5 | GE | E | SC Plant | GT13E2 | 210 | 38 | 8,980 | 50 | 43.51846 |
| 6 | GE | E | SC Plant | 7E.03 | 91 | 33.9 | 10,060 | 60 | 21.126 |
| 7 | GE | E | CC Plant | 9E.03 | 204 | 53.3 | 6399 | 50 | 30.12452 |
| 8 | GE | E | CC Plant | 9E.04 | 216 | 54.9 | 6220 | 50 | 31.00431 |
| 9 | GE | E | CC Plant | GT13E2 | 305 | 55.1 | 6189 | 50 | 43.56104 |
| 10 | GE | E | CC Plant | 7E.03 | 142 | 52.5 | 6,505 | 60 | 21.31638 |
| 11 | GE | F | SC Plant | 6F.01 | 57 | 38.4 | 8,880 | 50/60 Hz (Geared) | 11.68062 |
| 12 | GE | F | SC Plant | 6F.03 | 88 | 36.8 | 9,277 | 50 | 18.83945 |
| 13 | GE | F | SC Plant | 9F.03 | 265 | 37.8 | 9,020 | 50 | 55.16077 |
| 14 | GE | F | SC Plant | 9F.04 | 288 | 38.7 | 8,810 | 50 | 58.55262 |
| 15 | GE | F | SC Plant | 9F.05 | 314 | 38.6 | 8,846 | 50 | 64.09948 |
| 16 | GE | F | SC Plant | 9F.06 | 359 | 41.9 | 8,146 | 50 | 67.48648 |
| 17 | GE | F | SC Plant | 7F.04 | 198 | 38.6 | 8,840 | 60 | 40.392 |
| 18 | GE | F | SC Plant | 7F.05 | 243 | 39.8 | 8,570 | 60 | 48.05792 |
| 19 | GE | F | CC Plant | 6F.01 | 85 | 57.9 | 5896 | 50/60 Hz (Geared) | 11.56523 |
| 20 | GE | F | CC Plant | 6F.03 | 135 | 56.9 | 5998 | 50 | 18.68608 |
| 21 | GE | F | CC Plant | 9F.03 | 412 | 59.1 | 5778 | 50 | 54.93545 |
| 22 | GE | F | CC Plant | 9F.04 | 443 | 60.2 | 5666 | 50 | 57.92395 |
| 23 | GE | F | CC Plant | 9F.05 | 493 | 60.7 | 5619 | 50 | 63.92693 |
| 24 | GE | F | CC Plant | 9F.06 | 532 | 62.2 | 5,459 | 50 | 67.01972 |
| 25 | GE | F | CC Plant | 7F.04 | 305 | 59.7 | 5,715 | 60 | 40.22481 |
| 26 | GE | F | CC Plant | 7F.05 | 376 | 60.4 | 5,649 | 60 | 49.01594 |
| 27 | GE | H | SC Plant | 9HA.01 | 446 | 43.1 | 7,910 | 50 | 81.41215 |
| 28 | GE | H | SC Plant | 9HA.02 | 571 | 44 | 7,740 | 50 | 101.9894 |
| 29 | GE | H | SC Plant | 7HA.01 | 290 | 42 | 8,120 | 60 | 54.34154 |
| 30 | GE | H | SC Plant | 7HA.02 | 384 | 42.6 | 8,009 | 60 | 70.97206 |

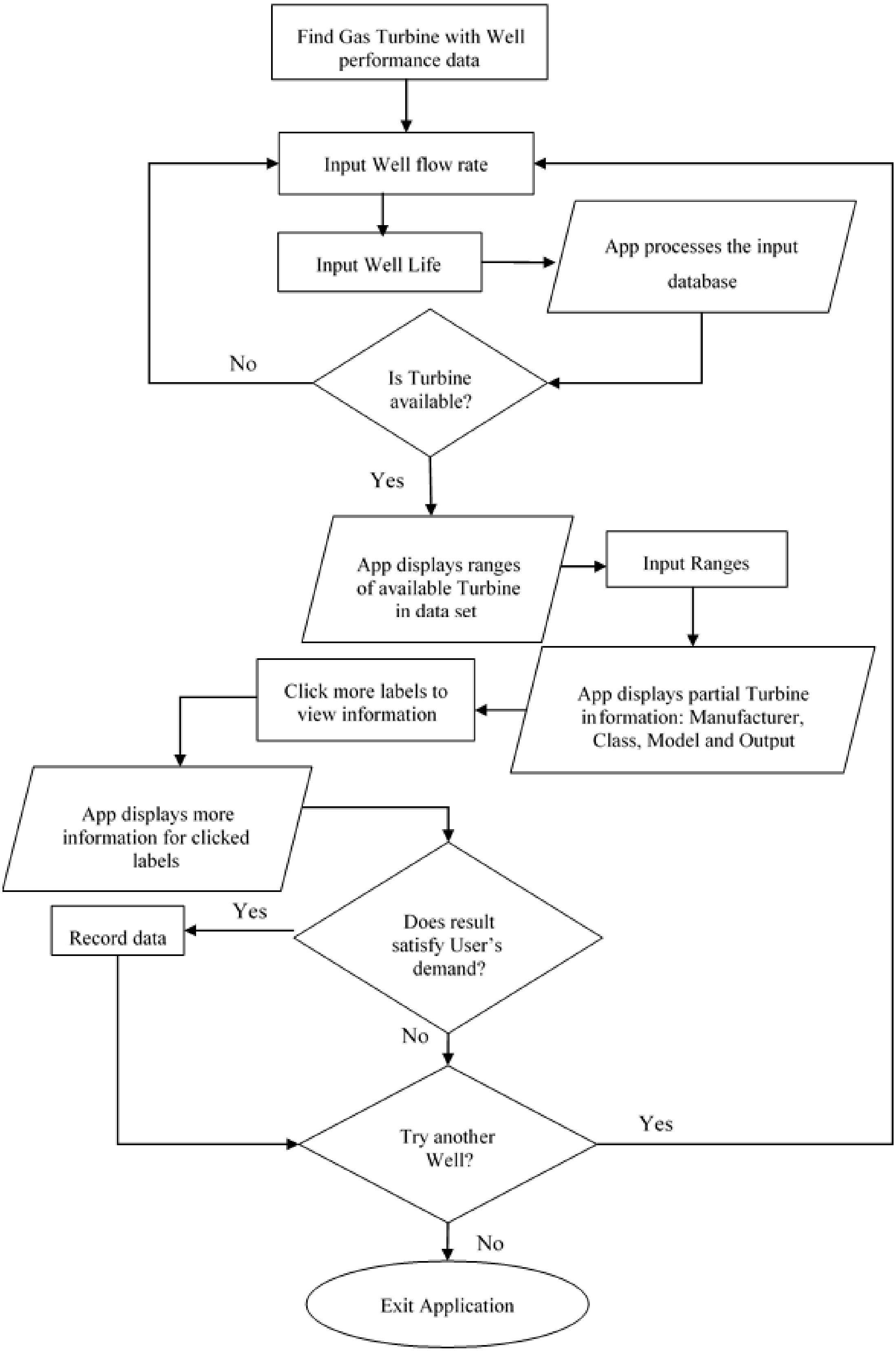
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 31 | GE | H | SC Plant | 7HA.03 | 430 | 43.2 | 7,897 | | 78.36254 |
| 32 | GE | H | CC Plant | 9HA.01 | 661 | 63.5 | 5378 | 50 | 82.03518 |
| 33 | GE | H | CC Plant | 9HA.02 | 838 | 64.1 | 5320 | 50 | 102.8806 |
| 34 | GE | H | CC Plant | 7HA.01 | 438 | 62.3 | 5,481 | 60 | 55.40026 |
| 35 | GE | H | CC Plant | 7HA.02 | 573 | 63.4 | 5,381 | 60 | 71.15338 |
| 36 | GE | H | CC Plant | 7HA.03 | 640 | 63.9 | 5,342 | | 78.89723 |
| 37 | GE | AD | SC Plant | TM2500 | 33.6 | 34.8 | 9,794 | 50 | 7.59412 |
| 38 | GE | AD | CC Plant | TM2500 | 48.4 | 49.8 | 6,851 | 50 | 7.65204 |
| 39 | GE | AD | SC Plant | TM2500 | 35.9 | 36.6 | 9,330 | 60 | 7.72955 |
| 40 | GE | AD | CC Plant | TM2500 | 50.5 | 50.9 | 6,703 | 60 | 7.81157 |
| 41 | GE | AD | SC Plant | LM2500 | 23.1 | 33.2 | 10,265 | 50 | 5.47203 |
| 42 | GE | AD | SC Plant | LM2500 | 24.1 | 34.4 | 9,920 | 60 | 5.51705 |
| 43 | GE | AD | SC Plant | LM2500DLE | 21.8 | 34.7 | 9,835 | 50 | 4.94776 |
| 44 | GE | AD | SC Plant | LM2500DLE | 22.7 | 35.9 | 9,501 | 60 | 4.97706 |
| 45 | GE | AD | CC Plant | LM2500 | 34.2 | 49.1 | 6,943 | 50 | 5.47963 |
| 46 | GE | AD | CC Plant | LM2500 | 35 | 49.9 | 6,844 | 60 | 5.52785 |
| 47 | GE | AD | CC Plant | LM2500DLE | 32.8 | 52.2 | 6,533 | 50 | 4.94498 |
| 48 | GE | AD | CC Plant | LM2500DLE | 33.2 | 52.9 | 6,456 | 60 | 4.94629 |
| 49 | GE | AD | SC Plant | LM2500+ | 29.3 | 34.7 | 9,826 | 50 | 6.64389 |
| 50 | GE | AD | SC Plant | LM2500+ | 31 | 36.1 | 9,453 | 60 | 6.76253 |
| 51 | GE | AD | SC Plant | LM2500+DLE | 30.1 | 36.5 | 9,338 | 50 | 6.48632 |
| 52 | GE | AD | SC Plant | LM2500+DLE | 30.6 | 38 | 9,482 | 60 | 6.69575 |
| 53 | GE | AD | CC Plant | LM2500+ | 41.5 | 49.2 | 6,931 | 50 | 6.63777 |
| 54 | GE | AD | CC Plant | LM2500+ | 43 | 50.1 | 6,809 | 60 | 6.75662 |
| 55 | GE | AD | CC Plant | LM2500+DLE | 44 | 53.4 | 6,384 | 50 | 6.48222 |
| 56 | GE | AD | CC Plant | LM2500+DLE | 43.9 | 54.2 | 6,299 | 60 | 6.38137 |
| 57 | GE | AD | SC Plant | LM2500+G4 | 33.6 | 34.6 | 9,870 | 50 | 7.65305 |
| 58 | GE | AD | SC Plant | LM2500+G4 | 36.2 | 36.5 | 9,348 | 60 | 7.80918 |
| 59 | GE | AD | SC Plant | LM2500+G4 DLE | 32.5 | 36.5 | 9,352 | 50 | 7.014 |
| 60 | GE | AD | SC Plant | LM2500+G4 DLE | 33.6 | 38.4 | 8,897 | 60 | 6.8986 |
| 61 | GE | AD | CC Plant | LM2500+G4 | 48.2 | 49.6 | 6,884 | 50 | 7.65713 |
| 62 | GE | AD | CC Plant | LM2500+G4 | 50.3 | 50.7 | 6,729 | 60 | 7.81082 |
| 63 | GE | AD | CC Plant | LM2500+G4 DLE | 47.7 | 53.8 | 6,343 | 50 | 6.98218 |
| 64 | GE | AD | CC Plant | LM2500+G4 DLE | 47.7 | 54.7 | 6,239 | 60 | 6.8677 |
| 65 | GE | AD | SC Plant | LM6000 PC | 45 | 39.4 | 8,651 | 50 | 8.98373 |
| 66 | GE | AD | SC Plant | LM6000 PC | 50 | 39.4 | 8,651 | 60 | 9.98192 |
| 67 | GE | AD | SC Plant | LM6000 PG | 55 | 39.3 | 8,692 | 50 | 11.03215 |
| 68 | GE | AD | SC Plant | LM6000 PG | 57 | 39.3 | 8,692 | 60 | 11.43332 |
| 69 | GE | AD | SC Plant | LM6000 PF | 44 | 41.2 | 8,281 | 50 | 8.4084 |
| 70 | GE | AD | SC Plant | LM6000 PF | 49 | 41.2 | 8,281 | 60 | 9.3639 |
| 71 | GE | AD | SC Plant | LM6000 PF + | 53 | 41.3 | 8,271 | 50 | 10.11607 |
| 72 | GE | AD | SC Plant | LM6000 PF + | 58 | 41.3 | 8,271 | 60 | 11.07042 |
| 73 | GE | AD | CC Plant | LM6000 PC | 59 | 51.9 | 6,573 | 50 | 8.94939 |
| 74 | GE | AD | CC Plant | LM6000 PC | 66 | 51.9 | 6,573 | 60 | 10.01118 |
| 75 | GE | AD | CC Plant | LM6000 PG | 73 | 52.2 | 6,535 | 50 | 11.00896 |
| 76 | GE | AD | CC Plant | LM6000 PG | 76 | 52.2 | 6,535 | 60 | 11.46138 |
| 77 | GE | AD | CC Plant | LM6000 PF | 58 | 55.2 | 6,179 | 50 | 8.27035 |
| 78 | GE | AD | CC Plant | LM6000 PF | 64 | 55.2 | 6,179 | 60 | 9.12591 |
| 79 | GE | AD | CC Plant | LM6000 PF + | 70 | 55.9 | 6,105 | 50 | 9.86192 |
| 80 | GE | AD | CC Plant | LM6000 PF + | 77 | 55.9 | 6,105 | 60 | 10.84812 |
| 81 | GE | AD | SC Plant | LMS100 | 117 | 43.1 | 7,925 | 50 | 21.3975 |
| 82 | GE | AD | SC Plant | LMS100 | 117 | 44.2 | 7,718 | 60 | 20.8386 |
| 83 | GE | AD | SC Plant | LM9000 (Low Nox) | 67 | 41.8 | 8,155 | 50 | 12.60888 |
| 84 | GE | AD | SC Plant | LM9000 (Spirint) | 75 | 42.1 | 8,096 | 60 | 14.01231 |
| 85 | GE | AD | CC Plant | LMS100 | 142 | 52.2 | 6,540 | 50 | 21.43108 |
| 86 | GE | AD | CC Plant | LMS100 | 140 | 53 | 6,438 | 60 | 20.79969 |
| 87 | GE | AD | CC Plant | LM9000 (Low Nox) | 88 | 55.9 | 6,109 | 50 | 12.40597 |
| 88 | GE | AD | CC Plant | LM9000 (Spirint) | 95 | 54.9 | 6,220 | 60 | 13.63615 |
| 89 | SIEMENS | H | SC Plant | SGT5-8000HL | 481 | 42.6 | 8006 | 50 | 88.86893 |
| 90 | SIEMENS | H | SC Plant | SGT5-8000HL | 593 | 42.8 | 7972 | 50 | 109.095 |
| 91 | SIEMENS | H | SC Plant | SGT6-9000HL | 405 | 42.6 | 8010 | 60 | 74.86271 |
| 92 | SIEMENS | H | CC Plant | SGT5-8000HL | 708 | 63 | 5416 | 50 | 88.48627 |
| 93 | SIEMENS | H | CC Plant | SGT5-9000HL | 870 | 63 | 5416 | 50 | 108.7331 |
| 94 | SIEMENS | H | CC Plant | SGT6-9000HL | 595 | 63 | 5416 | 60 | 74.36346 |
| 95 | SIEMENS | H | SC Plant | SGT5-8000H | 450 | 41 | 8322 | 50 | 86.41904 |
| 96 | SIEMENS | H | CC Plant | SCC5-8000H | 665 | 61 | 5583 | | 85.67208 |
| 97 | SIEMENS | H | SC Plant | SGT6-8000H | 310 | 40 | 8530 | 60 | 61.02483 |
| 98 | SIEMENS | H | CC Plant | SCC6-8000H | 460 | 61 | 5611 | | 59.56374 |
| 99 | SIEMENS | F | SC Plant | SGT5-4000F | 329 | 41 | 8322 | 50 | 63.18192 |
| 100 | SIEMENS | F | CC Plant | SCC5-4000F | 475 | 59.7 | 5715 | | 62.64888 |
| 101 | SIEMENS | F | SC Plant | SGT6-5000F(A) | 215 | 39.5 | 8638 | 60 | 42.85977 |
| 102 | SIEMENS | F | SC Plant | SGT6-5000F(B) | 260 | 40 | 8530 | 60 | 51.18212 |
| 103 | SIEMENS | F | CC Plant | SGT6-5000F(A) | 325 | 59.5 | 5734 | 60 | 43.0072 |
| 104 | SIEMENS | F | CC Plant | SGT6-5000F(B) | 387 | 59.6 | 5725 | 60 | 51.127 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 105 | SIEMENS | E | CC Plant | SGT6-2000E | 117 | 35.4 | 9638 | 60 | 26.02355 |
| 106 | SIEMENS | E | CC Plant | SCC6-2000E | 174 | 52.2 | 6533 | 60 | 26.23372 |
| 107 | SIEMENS | E | SC Plant | SGT-800E(A) | 49.9 | 39.4 | 8670 | 50/60 | 9.98347 |
| 108 | SIEMENS | E | SC Plant | SGT-800E(B) | 54 | 39.1 | 8726 | 50/60 | 10.87344 |
| 109 | SIEMENS | E | SC Plant | SGT-800E(C) | 57 | 40.1 | 8502 | 50/60 | 11.18329 |
| 110 | SIEMENS | E | SC Plant | SGT-800E(D) | 62.5 | 41.1 | 8302 | 50/60 | 11.97394 |
| 111 | SIEMENS | E | CC Plant | SGT-800E(A) | 71.2 | 57.2 | 5969 | | 9.8081 |
| 112 | SIEMENS | E | CC Plant | SGT-800E(B) | 77.3 | 56.9 | 5993 | | 10.69067 |
| 113 | SIEMENS | E | CC Plant | SGT-800E(C) | 80.7 | 57.9 | 5896 | | 10.98085 |
| 114 | SIEMENS | E | CC Plant | SGT-800E(D) | 88 | 59 | 5782 | | 11.74127 |
| 115 | SIEMENS | | SC Plant | SGT-750 | 39.8 | 40.3 | 8456 | 50/60 | 7.7669 |
| 116 | SIEMENS | | CC Plant | SGT-750 | 51.55 | 53.25 | 6407 | | 7.62215 |
| 117 | SIEMENS | | SC Plant | SGT-700 | 32.8 | 37.2 | 9170 | | 6.94108 |
| 118 | SIEMENS | | CC Plant | SGT-700 | 45.2 | 52.3 | 6517 | | 6.79793 |
| 119 | SIEMENS | | SC Plant | SGT-600 | 24.5 | 33.6 | 10161 | 50/60 | 5.74465 |
| 120 | SIEMENS | | CC Plant | SGT-600 | 35.9 | 49.9 | 6843 | 50/60 | 5.66936 |
| 121 | SIEMENS | | SC Plant | SGT-400(A) | 10.4 | 34.8 | 9802 | 50/60 | 2.35256 |
| 122 | SIEMENS | | SC Plant | SGT-400(B) | 12.9 | 34.8 | 9815 | 50/60 | 2.92174 |
| 123 | SIEMENS | | SC Plant | SGT-400(C) | 14.3 | 35.4 | 9647 | 50/60 | 3.18347 |
| 124 | SIEMENS | | SC Plant | SGT-300 | 7.9 | 30.6 | 11159 | 50/60 | 2.03431 |
| 125 | SIEMENS | | SC Plant | SGT-100(A) | 5.05 | 30.2 | 11292 | 50/60 | 1.31599 |
| 126 | SIEMENS | | SC Plant | SGT-100(B) | 5.4 | 31 | 11007 | 50/60 | 1.37164 |
| 127 | SIEMENS | AD | SC Plant | SGT-A65 (50Hz DLE) | 61.9 | 43.34 | 7874 | 50 | 11.24701 |
| 128 | SIEMENS | AD | SC Plant | SGT-A65 (50Hz DLE with ISI) | 65.9 | 43.8 | 7799 | 50 | 11.85993 |
| 129 | SIEMENS | AD | SC Plant | SGT-A65 (60Hz DLE) | 59.6 | 43.2 | 7895 | 60 | 10.8591 |
| 130 | SIEMENS | AD | SC Plant | SGT-A65 (60Hz DLE with ISI) | 64.9 | 43.3 | 7877 | 60 | 11.79778 |
| 131 | SIEMENS | AD | SC Plant | SGT-A65 (50Hz WLE with ISI) | 67.4 | 41.3 | 8269 | 50 | 12.8611 |
| 132 | SIEMENS | AD | SC Plant | SGT-A65 (60Hz WLE with ISI) | 70.8 | 41.4 | 8242 | 60 | 13.46651 |
| 133 | SIEMENS | AD | CC Plant | SGT-A65 (DLE) | 73 | 54.6 | 6249 | 50 | 10.52709 |
| 134 | SIEMENS | AD | CC Plant | SGT-A65 (DLE with ISI) | 83 | 54.2 | 6204 | 50 | 11.88383 |
| 135 | SIEMENS | AD | SC Plant | SGT-A45 (15 degree ambient) | 41 | 38.9 | 8777 | 50 | 8.30419 |
| 136 | SIEMENS | AD | SC Plant | SGT-A45 (30 degree ambient) | 39.3 | 38.3 | 8914 | 50 | 8.08451 |
| 137 | SIEMENS | AD | SC Plant | SGT-A45 (15 degree ambient) | 44 | 40.4 | 8477 | 60 | 8.60769 |
| 138 | SIEMENS | AD | SC Plant | SGT-A45 (30 degree ambient) | 39.6 | 39.4 | 8660 | 60 | 7.91409 |
| 139 | SIEMENS | AD | SC Plant | SGT-A35 (G62) DLE | 27.2 | 36.4 | 9387 | 50/60 | 5.89226 |
| 140 | SIEMENS | AD | SC Plant | SGT-A35 (GT62) DLE | 29.9 | 37.5 | 9089 | 50/60 | 6.27115 |
| 141 | SIEMENS | AD | SC Plant | SGT-A35 (GT61) DLE | 32.1 | 39.3 | 8681 | 50/60 | 6.43066 |
| 142 | SIEMENS | AD | SC Plant | SGT-A30 (DLE) 34MW | 32.5 | 38.3 | 8907 | 60 | 6.67998 |
| 143 | SIEMENS | AD | SC Plant | SGT-A30 34MW | 33.2 | 38.5 | 8873 | 60 | 6.79844 |
| 144 | SIEMENS | AD | SC Plant | SGT-A30 38MW | 37.4 | 39.7 | 8600 | 60 | 7.42289 |
| 145 | SIEMENS | AD | SC Plant | SGT-A30 (50Hz DLE) 34MW | 31.9 | 37.3 | 9141 | 50 | 6.729 |
| 146 | SIEMENS | AD | SC Plant | SGT-A30 38MW | 36.6 | 38.7 | 8813 | 50 | 7.44343 |
| 147 | SIEMENS | AD | CC Plant | SGT-A35 (G62) DLE | 37.7 | 50.2 | 6801 | 50/60 | 5.91651 |
| 148 | SIEMENS | AD | CC Plant | SGT-A35 (GT62) DLE | 39.8 | 51.4 | 6639 | 50/60 | 6.09809 |
| 149 | SIEMENS | AD | CC Plant | SGT-A35 (GT61) DLE | 42.6 | 52.8 | 6464 | 50/60 | 6.35472 |
| 150 | SIEMENS | AD | SC Plant | SGT-A05 (KB5S) | 4 | 29.7 | 11504 | 50/60 | 1.06188 |
| 150 | SIEMENS | AD | SC Plant | SGT-A05 (KB5S) | 4 | 29.7 | 11504 | 50/60 | 1.06188 |
| 151 | SIEMENS | AD | SC Plant | SGT-A05 (KB7S) | 5.4 | 32.3 | 10570 | 50/60 | 1.31719 |
| 152 | SIEMENS | AD | SC Plant | SGT-A05 (KB7HE) | 5.8 | 33.2 | 10282 | 50/60 | 1.3762 |

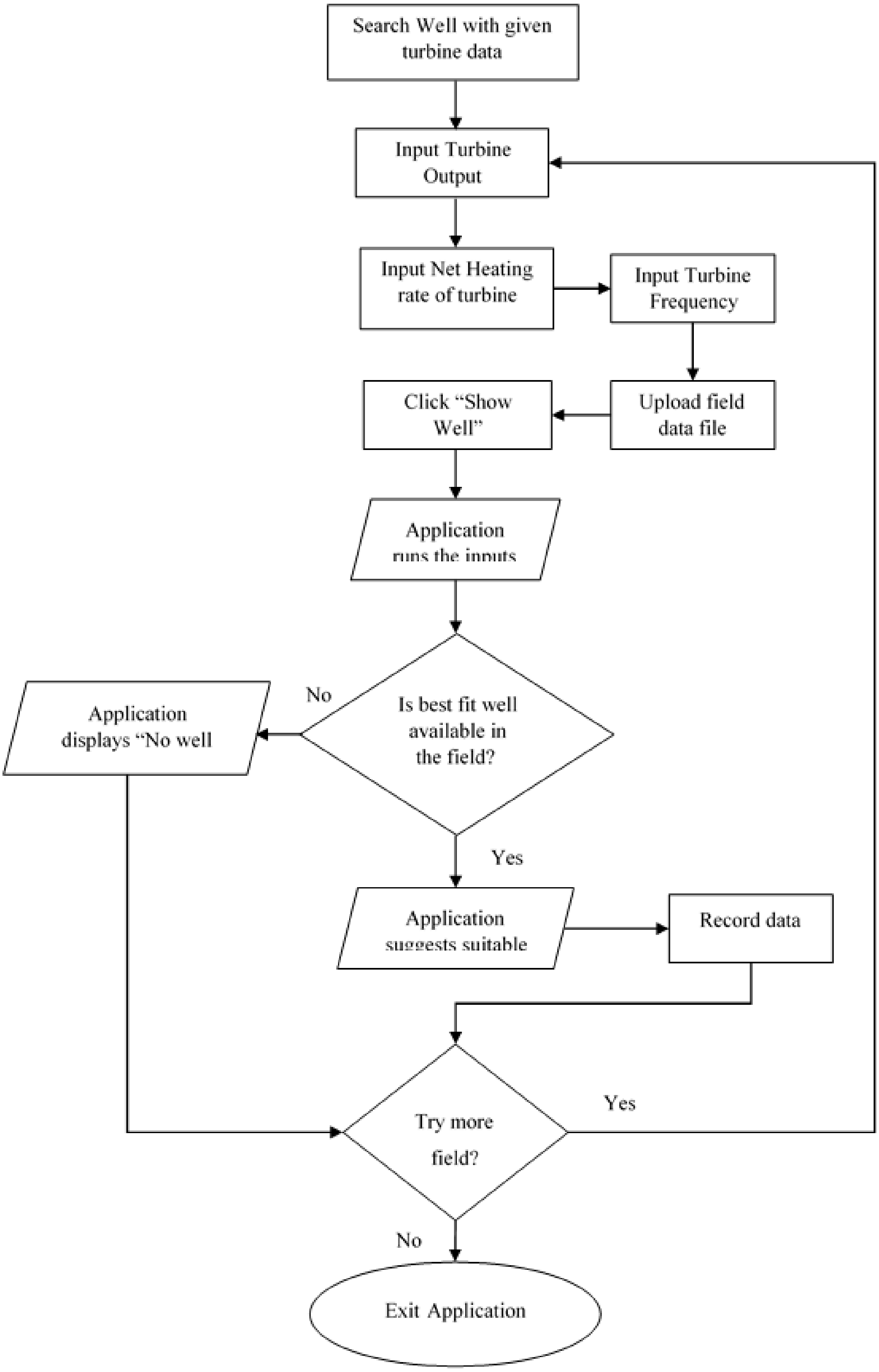
**Appendix B:** The Falcon PFD/Algorithms



**Appendix B1:** Application process flow chart



***Appendix B2:*** *Turbine Search Flow Chart/Algorithm*



***Appendix B3:*** *Well Search Flow Chart/Algorithm*