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WATER FLOW CONTROL SYSTEM BASED ON "RUN – OFF – RIVER" HYBRID POWER STATION

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ABSTRACT

The establishment location of the renewable power resources requires serious measurements and analysis in order to estimate and dominate the performance and the cost of the power station with respect to location impairments. In this paper, a unique methodology is presented to model the power systems in critical specific locations with respect to the formalization of the natural geographical area. The geographical impairment that is chosen as the case study in this work is the declinations of the river based earth surface at Altun-Kopru town in Iraq. A hybrid power system was chosen to study and apply the idea. In addition, the hybrid power station is modeled using both hydro and wind turbines to provide a specific load with the required power. The proposed idea can be applied by specifying the point that the river declines, then creating a water channel to keep the water in the same level before declination phenomenon starts. In contrast, the channel leads river water to the critical location in order to be fallen down to operate the hydro turbine in certain flow ratios and separately to fill a Tank as water preservation model. In accordance, the main power was produced primarily depending on the hydro turbine and secondarily on the wind turbine. Moreover, four hydroelectric power considerations were studied in order to show their impacts on the performance and cost of the renewable power stations. For more precise analysis, extending power form the grid has shown that proposed stand-alone system in the whole case studies unconditionally is always cheaper than the breakeven grid network. Finally, a modular control system is designed in order to dominate water flow ratio based on Tank control unit.

Keywords: Hybrid Power Systems; Power System Performance; Cost Evaluation; HOMER Software.

1. INTRODUCTION

Power generation phenomenon is considered the most important and plentiful resources throughout the universe. The generated power is represented as the energy that is an ultimate element specially in promoting several activities such as living, transportation, and even developing serious issues economically (Bilal Abdullah Nasir, 2014; Mohibullah, M. A. R., MohdIqbal Abdul Hakim, 2004). The most critical energy degradations are recently revealed such as climate conditions, oil crisis, and the need for the electricity based on different resources all around the world. The presented crisis have elevated drastically, lead system designers to think wisely and propose unconventional technological precautions. Usually, designers need critical solutions of power generation, due to the complications appear in a specific renewable energy locations. Hereby, the most familiar options that keep the proposed areas, uncontaminated is renewable power system identified individually by photovoltaic components PV, Wind turbines, Hydroelectric power turbines or even by hybrid power systems. Hydro – electric power generator is considered one of the solutions employed to solve the complex problems that might be encountered. Power generation systems based Hydro – electric methodology, produces energy sources by flowing the water from a specific elevation. The amount of the energy depends considerably on water fall strength depending on the gravity. In contrast, mechanical energy is realized as long as the water is falling over hydro turbine blades. Hereby, Hydro – electric power phenomenon will be exposed, where the electrical energy is produced based on the mechanical energy that is formed by generating actuators. It is worth mentioning that 16 % of the electricity all around the universe employs massive hydro – electric stations with respect to waterfall control systems and location complexity (Dilip Singh, 2009). The proposed hydroelectric systems are considerably employed across the rivers and water falls to generate power approximately around 5 – 100 kW. The working principle of hydroelectric power plants can be represented by storage unit that stores energy as water. The factors that excite power system designers to create systems included with hydroelectric power station, is that the energy effectiveness of such systems reach to 70 – 90 % comparing to the other renewable resource technologies. Moreover, the highest capacity opportunity that is given by such power plants could be more than 50 % comparing to the other technological solar resources identified by solar and wind power 10% and 30% respectively. In addition, the realized output power ratio can be changed too heavily per day particularly in winter season, where the maximum power production is achieved (Bilal Abdullah Nasir, 2014). It is worth mentioning that the studies and the researches confirmed that the micro hydro power plant up to 100 kW is considered better comparing with the smallest one that provides power up to 10 MW. The reason is that the micro hydro power plants are smaller size, lower costs, and can be implemented too easily to provide a specific region with the required power. Contrariwise, the small hydro power plants come with higher capital costs and show technical hitches throughout implementation. This paper presents a modern idea applied in Iraq, which states that such systems work based on 'run of river' methodology at little Zab river, which means that installation complexity will be eliminated. Water channel is created regularly with respect to the proposed river in order to lead the water along the channel to be driven down towards the hydroelectric turbine. In this research work, it is intended to evaluate the performance and the cost of the proposed hybrid power system. In addition, the created stand-alone power system was connected to the grid extension to show up the performance differences among several cases. The compassion processes with grid extension lead to robust and powerful theoretical analysis in order to illustrate the status of a specific renewable power system with respect to its components. Most of works have shown the results of grid extension compassion with stand-alone systems. In this paper, it is intended to mention one of these works as a background for our proposed work results. The research work titled "Evaluation of stand-alone hybrid system" employed such an idea in order to reach the optimum results of the grid extension comparison (SAMEER S. AL-JUBOORI, ALI H. MUTLAG, 2014). HOMER software based results stated that the sand-alone system created depending on their proposed hybrid system was considered better and cheaper than breakeven grid extension for a distance specified by 9.24 Km with respect to a net price cost about 316.827$. This means, the distance from the proposed location to the identified power station is about 10 Km. Hereby, the stand-alone system is considered cheaper than the breakeven grid extension as exposed in Fig.1.

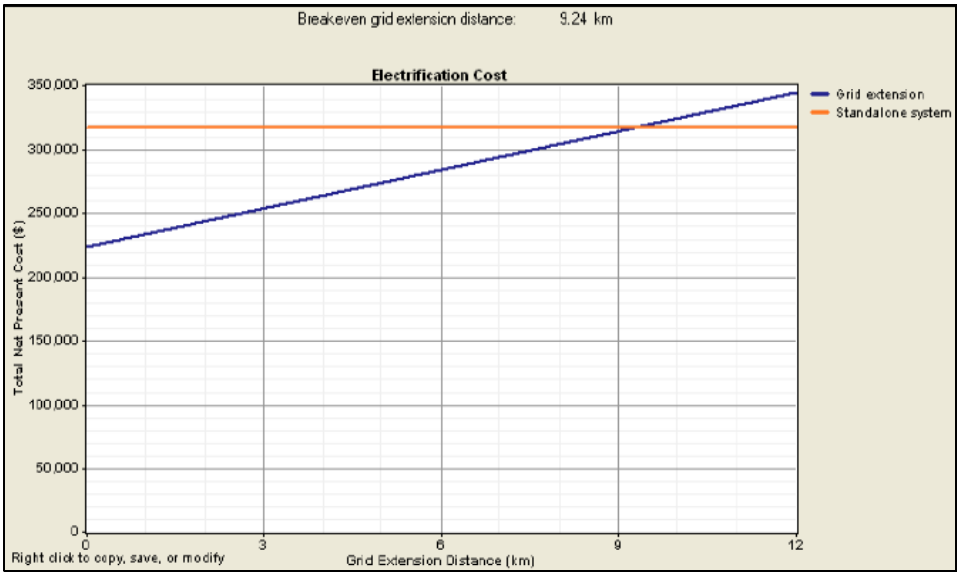

Figure1. Breakeven grid extension result

In addition, the breakeven grid extension distance is measured by Km and can be fulfilled based on the set of equations given by HOMER software as follows (Tom Lambert, 2007):

$$D_{grid} = \frac{c_{NPC} \cdot CRF(i,R_{proj}) - c_{power} \cdot E_{demand}}{c_{cap} \cdot CRF(i,R_{proj}) + c_{om}} \quad \text{..................(1)}$$

Where, C_{NPC} is total net cost of the stand-alone system, CRF is the capital recovery factor, i is the interest rate (%), R_{proj} is the project lifetime (yr), c_{power}, annual electricity demand measured by (kWh/yr), c_{power} is the cost power of the grid extension ($/kWh), c_{cap} is the capital cost of the grid extension ($/km), and c_{om} operating and maintenance O&M of the grid extension ($/yr/km).

Furthermore, the capital recover factor CRF is the ratio of computing the present value of a unit, and given in HOMER as follows:

$$CRF(i,N) = \frac{i(1+i)^N}{(1+i)^N - 1} \quad \text{...(2)}$$

Where, i is the interest rate in reality, and N is years number. As an example, let's consider that i = 9%, and N = 6 years, then based on Eq.2, CRF is 0.2229. Furthermore, with a 1000$ loan and 9% interest, then the present value in six years is 1000$ with respect to payment of 222.9$.

The interest rate i, which also known as real interest rate in HOMER, is the ratio of a discount applied in the process of turning between onetime and annualized costs. The calculation of the annual real interest ratio of the nominal interest ratio is given in Homer as follows (Tom Lambert, 2007):

$$i = \frac{i' - f}{1+f} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where, i' is the nominal interest rate (%), and f is the annual inflation rate (%). As an example, suppose that $\mathrm{i}' = 7\%$ with respect to inflation rate of $\mathrm{f} = 2\%$, then $\mathrm{i} = 4.9\%$.

2. HOMER SOFTWARE

Homer is considered as one of the important power optimization programs due to wide usability and demand all around the universe. The program is identified and developed through Mistaya engineering specialized for the employ and implementation of national renewable energy laboratory (NREL) in USA. This organization facilitates the difficulties regarding appreciation issues for the design of grid connected and renewable solar systems based on different components. The use of such an active program has simplified a lot of decisions related to the design of solar systems, the items that systems are made of, the size of the proposed system and the specification of each employed component. The decision simplifications fascinated the designer due to the harsh conditions that energy and solar system were known due to the variation of the cost and the high technological prosperity nowadays appeared (T. Givler, P. Lilienthal, 2005). The key reason for paying this great attention towards HOMER is the analysis, sensitivities, and good estimations, which have awarded simple evaluation for many applicable solar systems (M . Ali, S. Algburi, etc, 2016; Sarmad Nozad Mahmood, Ali Abdulabbas, etc, 2017; A. Ruhul, R.B. Roy, etc, 2014).

3. LITTLE ZAB RIVER IDENTIFICATION

Little Zab river starts raising form Zagros mountain in Iran at height of 3000 meters (9.800) feet. Initially, the river follows its path alongside mountain chains that creates Zagros. The river then streams through valleys that are as a matter of fact, located along the North West – South East axis to Zagros mountain chains in order to change its way precipitously through the chains. Little Zab river arrives south Dukan plain where the tendency of the river starts following the westward path. In the next stage, the river is turned to the southwest upstream from Altun-Kopru town then joins the Tigris river at Al Zab town. Baneh river and Qala Chulan as tributaries link with little Zab upstream from Dukan. In addition, several smaller streams join the little Zab in Ranya plain that is currently submerge by Dukan lake. For more details, the length of little Zab river is 402 Km – 250 miles, basin of 22000 Km^2 – 8.494^2 miles. Originally, the river starts streaming from Zagros mountains – Iran with elevation around 3000 M – 9.843 FT, and finally settled down in the location identified by Tigris, Kirkuk – Erbil Governorate – Iraqi Kurdistan as the google map snapshot shown in Fig.2, with coordinates of 35o 14’17’ North – 43o 26’11’ East, which can be specified in decimal as 35.238056, 43.436389 – Altun-Kopru – Iraq. The oldest dam is created in Iraq for power production and irrigation processes is known as Dukan dam, which is constructed on the little Zab river on 1959 with almost 80 Km from Altun-Kopru town (Waterkeepers Alliance - Iraq, 2013), around the boarder of Al-Sulaymaniyah Governorate.

Figure 2. Google map view for the proposed river

The river creates a border between Erbil – Sulaimania governorate, and between Erbil – Kirkuk governorate. Water levels depend considerably on snowmelt and the drizzle all around the year. The water flow ratio from Dukan reservoir can be discharged maximally on July, August, and September. The amount of water in the reservoir can be changed drastically regarding the season due to the flooding and dryness. However, there exist storage units for Dukan reservoir that control discharge amount in the critical cases. It is worth mentioning that the annual average discharge in Dukan reservoir that creates a part of little Zab is recorded to be lower particularly in the last 40 years, and the water stage in the little Zab river is considered inconstancy and not slippery in the period between 2005 – 2011 years (MAZIN A. A. AL-ABADI, 2013).

4. THE HYDROELECTRIC POWER PLANT

The establishment of hydroelectric power stations can be satisfied mainly by fulfilling number of necessary requirements identified by:

4.1. *Hydroelectric Head*

In this section, the effective head of the proposed turbine is discussed in order to decide the suitable turbine height to control water flow rate and consequently the production of the power. As mentioned before that water flow rate is considered the first vital part that controls the amount of the produced power. In this study, three options of hydro head are taken into consideration in HOMER software in order to evaluate the performance of the system for the nominal hydro power production and cost appreciations over each option. Head height options are chosen as 15, 20, 25 meters. The available head is the vertical drop between two items identified by the intake and turbine. These items can be affected mainly by friction loss in the pipeline that make the effective head a little bit lesser than the available head depending on the net effective head h_{net} expression that is given as follows (Tom Lambert, 2007):

$$h_{net} = h * (1 - f_h) \quad \ldots\ldots (4)$$

Where, h is the available head measured by (m), f_h is the pipe head loss expressed in percentage (%). HOMER software starts changing hydroelectric output results each time the elements of the hydro output power are changed that is the realized output is satisfied as follows:

$$P_{hyd} = \frac{\daleth_{hyd} * P_{wa} * Gr * h_{net} * Q_{tur}}{1000\, W-kW} \ldots\ldots (5)$$

Where, P_{hyd} is the power of the hydro turbine measured in kW, $\daleth_{hyd}$ is the efficiency of the hydro turbine expressed in percentage (%), P_{wa} is water density that could be around 1000 kg / m3, Gr the gravity with respect to the acceleration which denoted as 9.81 m / s2, and Q_{tur} the flow rate of the hydro turbine. Furthermore, the term nominal hydropower means the power that would be realized with respect to the available head where water stream flow is equal to the design flow ratio of the hydro turbine. In this manner, Homer includes the efficiency in the calculation regardless the pipe head loss as follows:

$$P_{hyd,nom} = \frac{\daleth_{hyd} * P_{wa} * Gr * h * Q_{des}}{1000\, W-kW} \ldots\ldots (6)$$

Where, $P_{hyd,nom}$ is the nominal hydropower, and Q_{des} is the design flow ratio of the hydro turbine measured in m3 / s.

4.2. *Design Flow Rate*

The flow rate option is considered another factor that governs the performance and the cost of the renewable resources that depends considerably on the hydroelectric power stations to produce power. Water ratio effects mainly on the realized power as demonstrated in the set of equations (4, 5, and 6). As a comparison, it is intended to study the impact of the design flow rate on the performance and the cost of the system by adding three flow options identified by 30, 40, 50 Letter / Second. It is worth mentioning that the design flow rate can modify and alter the effectiveness of hydroelectric power plants by operating the turbine at its maximum efficiency in order to reach the maximum flow rate. More precisely, the minimum flow ratio is the minimum amount of water that can be allowed to be streaming through the hydro in a specific time. There exist an assumption based HOMER software states that the hydro turbine can operate if and only if the flow ratio is equal or little bit greater than the minimum flow value. Hereby, HOMER starts computing the minimum flow ratio Q_{min} as follows (Tom Lambert, 2007):

$$Q_{min} = W_{min} * Q_{des} \quad \text{……………………….………………(7)}$$

Where, W_{min} is the minimum flow ratio of the hydro turbine, Q_{des} is the design flow ratio of the hydro turbine. Furthermore, the maximum flow ratio is the maximum amount of water that can be allowed to be streaming through the hydro in a specific time. Hence, HOMER starts computing the maximum flow ratio Q_{max} as follows:

$$Q_{max} = W_{max} * Q_{des} \quad \text{…………………………………....(8)}$$

Where, W_{max} is the maximum flow ratio of the hydro turbine. In addition, Hydro turbine flow rate Q_{tur} is the amount of water that can be allowed to be streaming through the hydro turbine, and is given in HOMER as follows:

$$Q_{tur} = \begin{cases} 0 & if\ Q_{ava} < Q_{min} \\ Q_{ava} & if\ Q_{min} \le Q_{ava} \le Q_{max} \\ Q_{max} & if\ Q_{ava} > Q_{max} \end{cases} \quad \text{…………….(9)}$$

Where, $Q_{ava}$is the available flow rate to the hydro turbine measured in (m^3 / s), which is considered the maximum flow rate that could be handed over into the hydro turbine and can be calculated in HOMER as follows:

$$Q_{ava} = Q_{st} * Q_{res} \quad \text{…………………………...………….(10)}$$

Where, Q_{st} is total flow stream measured in (m3 / s), Q_{res} is residual flow measured in (m3 / s). Residual flow is the amount of water that should stay calm in the channel for environmental reasons that is the amount of water that cannot be handed over to be followed across the hydro turbine (Tom Lambert, 2007).

Hydro turbine flow rate Q_{tur} can be classified into three possibilities as demonstrated in Eq.9. HOMER software clarifies the three possibilities as follows:

- The available flow rate gets lesser than minimum flow rate, then there exists no water flow ratio.
- The mean available flow rate is realized when the flow ratio remain in a range between the minimum and maximum flow ratio.
- Finally, the available flow rate is considered maximum, when the available flow rate gets greater than the maximum flow rate.

4.3. *Pipe Head Loss*

The pipe head loss denoted as f_h, appears due to the frictional losses in the pipeline of the hydro turbine. The water is a viscid fluid travels in the pipe and generates friction in the form of pressure. HOMER represents this pressure in term of head loss, which is the perpendicular water drop during the flow. As a result, HOMER stated that high head creates low hydro systems; consequently a pipe head loss in between approximately (10 – 20) % will be realized. Whereas, low head systems results lowest pipe head loss around a few percentage. Finally, a comparison is occurred by changing over among three head loss possibilities of (5, 10, 15) %.

4.4. *Hydro Turbine Efficiency*

Hydro turbine effectiveness can be explained as the efficiency that the hydro turbine generates electricity from the mechanical power of the water. For more perspective confirmation, three options are taken into consideration in HOMER specified by (85, 95, 100) % to show up the impact of turbine efficiency on the performance and cost of the system. The efficiency of hydro turbine is considered the other cost and performance factor that allows an opportunity to create effective renewable system in order to reach the maximum power production with respect to the self-precautions taken into account to protect the environment.

5. THE PROPOSED SYSTEM UNIT

The proposed system idea was obtained due to the impairments of natural geographic areas that might be encountered in the locations that need to be provided with natural renewable energy systems. Several studies stated that such impairments can appear in our proposed location if power production system of hydroelectric plant is established to provide the location with renewable electricity. As mentioned before, Zab river raises from Zagros Mountain and follows its path inside Iraq to the end of path in order to join to the Tigris, at this point, the path of the river will be turned to follow another way to create Dukan river that is considered the start point of the proposed idea of this paper. The water starts rising towards the north to the place that identified by Kirkuk – Erbil Governorate – Iraqi Kurdistan at Altun-Kopru town. The natural geographical creation of Altun-Kopru earth made the whole town to be treated as a valley. This means, that the earth at the proposed town goes down as long as we move towards the north. According to the expression that clarifies water flow possibilities in Eq.9, and the background illustration given in head loss section, we state that as long as water falls from highest places, an energetic hydro system is realized. This declination in Altun-Kopru would drive the river down resulting a weakness in the strength of the water falling down on the blades of the hydro turbine. The proposed idea of the paper states that the river is tracked to find out the point that the declination starts. In that point, water channel is employed to create a new path straightly in order to drive a branch of the river towards the proposed hydro system location. The operation creates a sub river lead the water to complete its way before the declination towards hydro system location. This results the water to be kept in the highest levels providing the water with more falling strength regarding the difference in the height. Hereby, the water falling over turbine blades would operate in a grate efficiency reach to 100 % resulting maximum power production as the representation shown in Fig.3.

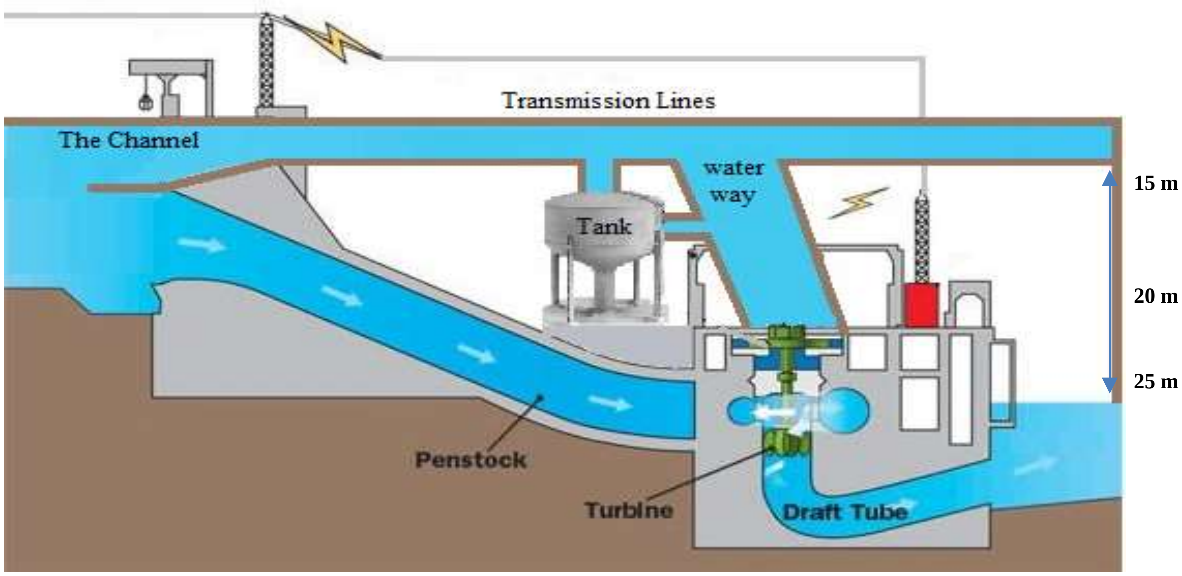

Figure 3. The simple representation of the proposed idea

Furthermore, the channel allows the water to be descended over hydro turbine and simultaneously stores a part of channel water in a tank. It is proposed to control the amount of the water falling over turbine blades by using a control unit. Under this act, the water stored in the tank might start pushing the water to the waterway in case of the flow ratio over the turbine decreased than the usual value with respect to variations of the three presented flow options (30, 40, 50) L/s. Waterway flow weakness assumption is taken into account, due to the unexpected impairments that might be encountered such as some kind of natural losses, or irrigation processes that might occur by the farmers over the channel particularly, during the way of the water out to provide the hydro turbine. The control module realization is considered extremely important to run the entire system up based on the tank. Hence, it is intended to use unique and robust microcontroller identified by Arduino microcontroller. The implementation and the programing simplicity, always excites the researchers to employ Arduino microcontrollers.

6. TANK CONTROL UNIT

This section focuses mainly on the control system design of a tank water streaming control. Honestly, the topic that is going to be unveiled in this section is treated as a subsystem of the huge power system identified above. The control part is simply constructed of three components identified by first, Arduino UNO microcontroller, which is an open source electric board that can easily work depending on the hardware and software. The proposed microcontroller deals with number of sensors and actuators to perform many tasks depending on the pins available in the board identified by digital and analog pins. The control processes can be realized based on Arduino Integrated Development Environment (IDE), which is considered the most popular programing Environment. Second, Liquid flow rate sensor that is a simple sensor constructed internally of a turbine wheel and two sided holes to let the water normally in and out. Externally, the sensor is equipped with three terminals represented by VCC, GND, and Signal terminal. The proposed wheel is rotated to different directions depending on the flow ratio over the wheel accordingly the liquid flow measurement is realized based on the number of rotations in a specific time. Hereby, it can be stated that the flow rate is directly proportional with wheel rotation speed. Third, external power specified by 9 volts in order to provide the microcontroller with suitable power. The proposed control unit can be modeled based on control system engineers method by plant, input, output, and disturbance signal. The plant module is the system that contains all task possibilities regardless of satisfying the specification required by the control system. The input is the water flow that can enter the system and analyzed later in another control block. Finally, the output is a resultant gain of the entire subsystem that is modified periodically using a closed loop feedback methodology as shown in Fig.4.

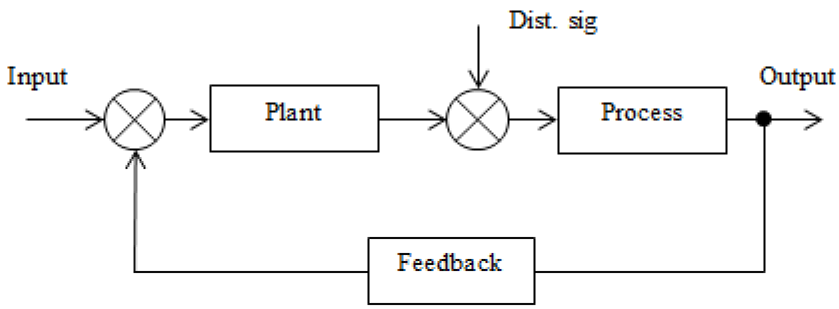

Figure 4. Control system design representation

The proposed control subsystem is built by satisfying the connection scheme shown in Fig.5, such that the signal terminal of the liquid sensor is attached to the digital pin of the microcontroller, VCC and GND terminals of the sensor are attached to the VCC and GND of the microcontroller respectively. The proposed liquid flow meter works based on voltage differencing principle realized from the applied electric filed of the device magnet. The amount of water falling on the blades of the turbine wheels, lead the rotor to be in a relative rotational movement. Wheel rotation generates voltages in the form of pulses that is the reason of connecting the signal terminal of the sensor to the pulse width modulation PWM pin identified by digital pin 2. The number of the pulses generated based on wheel rotation can realize water flow ratio depending on a simple mathematical expression.

In this liquid flow sensor, every 1 L of water can generate around 4.5 pulses per minute based on the voltage differencing reported by the magnetic field. As a result, for every litter of water passing through the module, a pulse counter would count 4.5 as pulses factor per minute, then the water flow ratio will be realizes by dividing the pulse counter by 4.5 pluses as follows:

$$Water\ Flow = \frac{pulse\ counter}{pulses\ factor} \quad (11)$$

Furthermore, form Eq.11, we can find out the flow ratio can be given in litters per second by dividing the realized flow rate value by 60 seconds, and multiplying the entire equation by 1000 as follows:

$$Water\ Flow\ (L/s) = \frac{water\ flow}{60} * 1000 \quad (12)$$

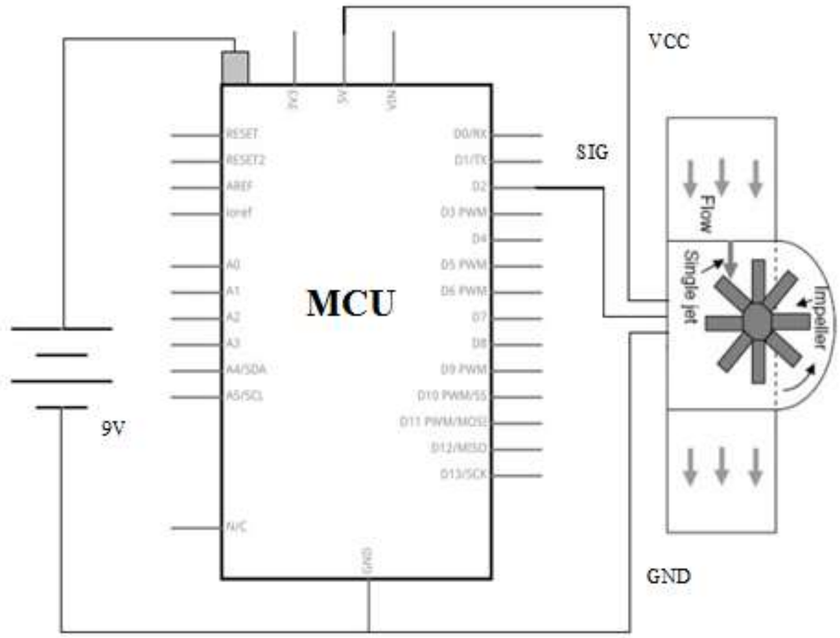

Figure 5. Control unit connection scheme

It is worth mentioning that the IDE code is omitted for clarity, however it is intended to represent the programming code as a flowchart module shown in Fig.6.

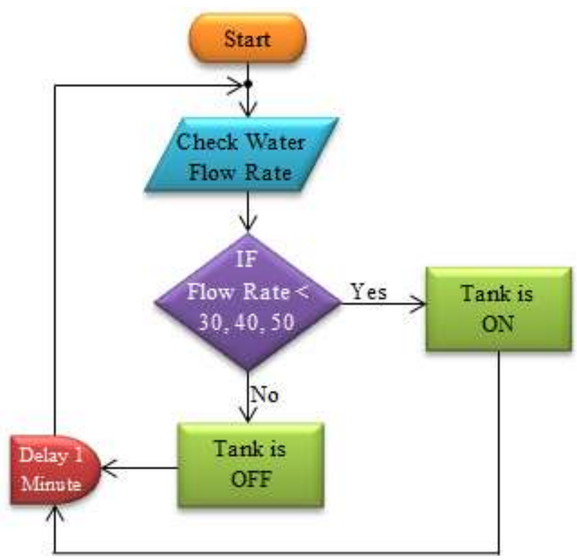

Figure 6. Programming code flowchart

The flowchart states, that the system starts checking the water flow strength based on the control system designed to manage the mater. Water flow density is checked in order to decide regarding the tank water to be push out to the water way or not. The microcontroller starts checking the flow ratio periodically every 1 minute over three possibilities (30, 40, 50) L/s separately. This means, that there exist systems might apply 30 or 40 or 50 L/s, in that case the program must be written based on the corresponding water flow density. Furthermore, the flow ratio is evaluated and the decision will be taken whether to activate / deactivate the tank accordingly.

7. HYBRID POWER SYSTEM STRUCTURE

The term hybrid is given to the systems that structured of several renewable components such as hydroelectric power plant, wind turbine, PV panels …etc. In this paper, the hybrid power system is constructed of two components identified by hydroelectric power station, and wind turbine, both employed to provide a primary load input with sufficient power. Hereby, it can be conclude that the entire hybrid power station elements are chosen as follows:

1. Primary load input.
2. Hydroelectric power station.
3. Fuhrlander30 Wind Turbine.

7.1. *Primary Load Input Setup*

The proposed load is chosen to be a small village at Altun-Kopru town with expected power consumption around **16 kW**, **158 kWh/d**. The village can be provided with the required power around 24 daily hours per month based on the hybrid power system that suggested in this paper. For more details, the power distribution in the proposed location per day is given in HOMER as shown in Table 1.

Table 1. The power distribution for the proposed village in 24 hours per day

Hour	Load (kW)	Hour	Load (kW)
00:00 – 01:00	4.000	12:00 – 13:00	8.000
01:00 – 02:00	4.500	13:00 – 14:00	8.000
02:00 – 03:00	4.500	14:00 – 15:00	8.500
03:00 – 04:00	5.000	15:00 – 16:00	8.500
04:00 – 05:00	5.500	16:00 – 17:00	9.000
05:00 – 06:00	5.500	17:00 – 18:00	9.000
06:00 – 07:00	6.000	18:00 – 19:00	8.000
07:00 – 08:00	6.500	19:00 – 20:00	7.000
08:00 – 09:00	6.500	20:00 – 21:00	6.000
09:00 – 10:00	7.000	21:00 – 22:00	6.500
10:00 – 11:00	7.570	22:00 – 23:00	5.000
11:00 – 12:00	8.000	23:00 – 00:00	4.000

7.2. *Hydroelectric Power Station*

The hydro turbine is considered the primary system component that the proposed load depends majorly on the amount of the power produced by the Hydro turbine. As mentioned before, that the hydro power station is constructed in HOMER based OFF-river methodology that is the technique that does not need to absorb the turbine in the river. In addition, it can be stated that the water strength information will be neglected. However, the matter was treated differently in HOMER software, it is worth mentioning that HOMER software does not allow using the hydro turbine without hydro resource information even in case of employing OFF-river technology. Hereby, the proposed hydroelectric power plant based HOMER uses the average monthly stream flow (SAMEER S. AL-JUBOORI, ALI H. MUTLAG, 2014) for the proposed Tigris River that rises later in Altun-Kopru town. For more clarity, it is intended to demonstrate the presented flow stream limitations as an information bar shown in Fig.7, for Tigris River to Dukan River, then flows its track down to Altun-Kopru town that is the point the proposal of this research paper starts taking place routinely.

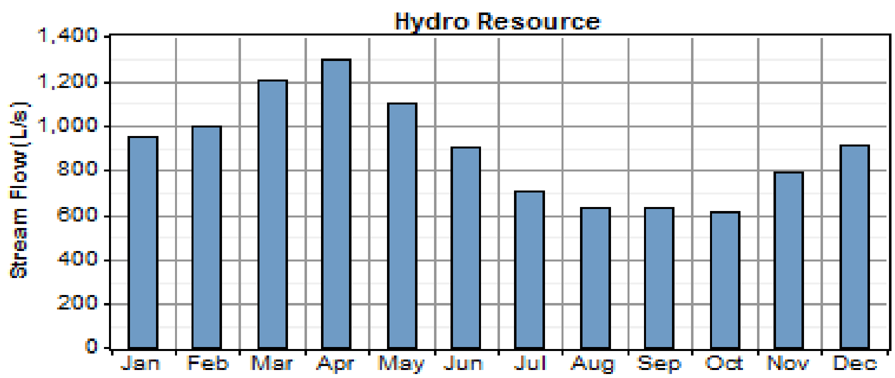

Figure 7. Flow stream limitation in Altun-Kopru town

Furthermore, it is worth mentioning that hydroelectric power considerations and the cost items for a lifetime of 25 years are chosen in HOMER as follows:

- Installation capital cost of 2000 $.
- Replacement cost of 1000 $.
- Operating and maintenance cost about 500 $/yr.

7.3. *Fuhrlander30 Wind Turbine*

The proposed wind turbine is denoted by FL30, with rotor diameter of (13m), tower of (26 – 30m) freestanding lattice and rated power of (30kW). It is worth mentioning that the FL30 produces power of (30kW), this means that the generate power is extremely sufficient to feed the proposed primary load. For more clarity, it is intended to demonstrate the power curve for FL30 as shown in Fig.8.

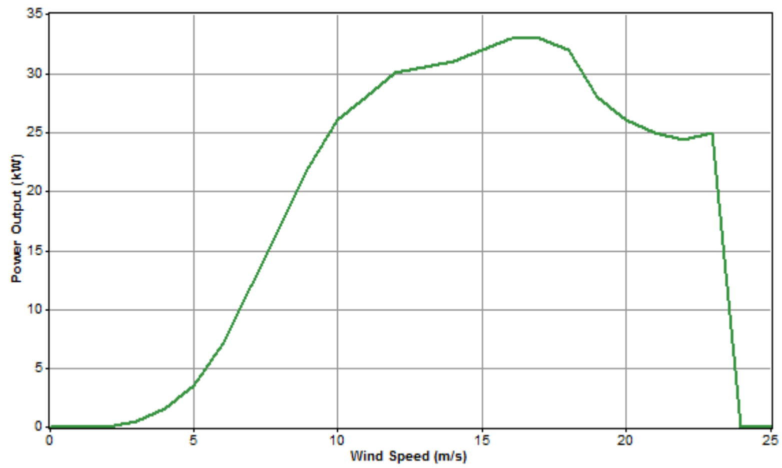

Figure 8. Fuhrlander30 wind turbine power curve

Moreover, the quantity and the cost items are chosen for FL30 as shown in Table 2 with a lifetime of (15) years (Staci Clark, 2009; John F. Maissan, 2006; Hossiean khalili, Ardeshir Arash1, etc, 2015).

Table 2. FL30 wind turbine costs items

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	**5300**	**1000**	**50**

Wind resources are chosen based on the proposed location at Altun-Kopru town (NASA, 2017; Sameer S. Al-Juboori, 2013) as the monthly average wind speed with respect to anemometer height of 10 m above earth surface as exposed in Fig.9.

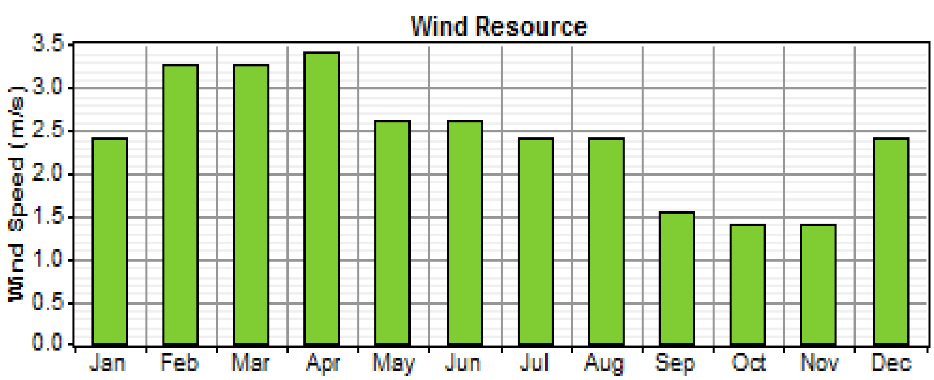

Figure 9. Monthly average wind speed

The monthly average electric production is represented, as the curve shown in Fig.10, which emphasizes that, the power production of the wind turbine in the hybrid power system is lesser than hydro turbine in some certain cases.

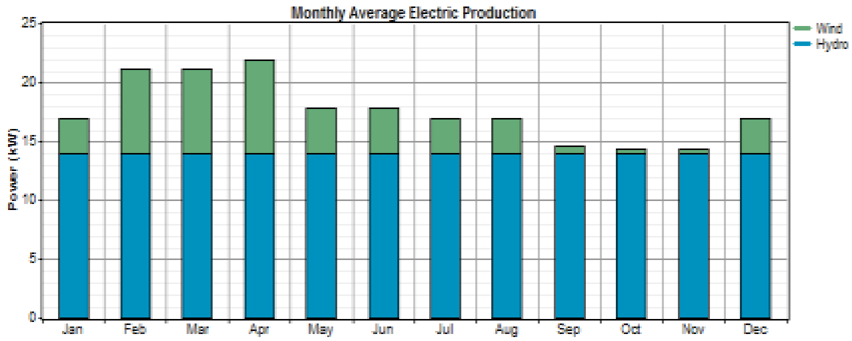

Figure 10. Monthly electric production of wind / hydro

8. HARVEST BASED ON PERFORMANCE & COST

The proposed power system design depends mainly on the first component identified by the hydroelectric power plant using 'run-off-river' manner. In this paper, it is intended to evaluate the performance and cost of the hybrid power system based on several hydro factors in order to study the difference among the cases that exposed as follows:

8.1. *Case Study 1*

Hydro Head = 20 m - -- Design Flow Rate = 50 L/S -- Hydro Turbine Efficiency= 100 % -- Hydro Head Loss= 5 %
The performance simulation results regarding case study 1, are given as shown in Fig.11.

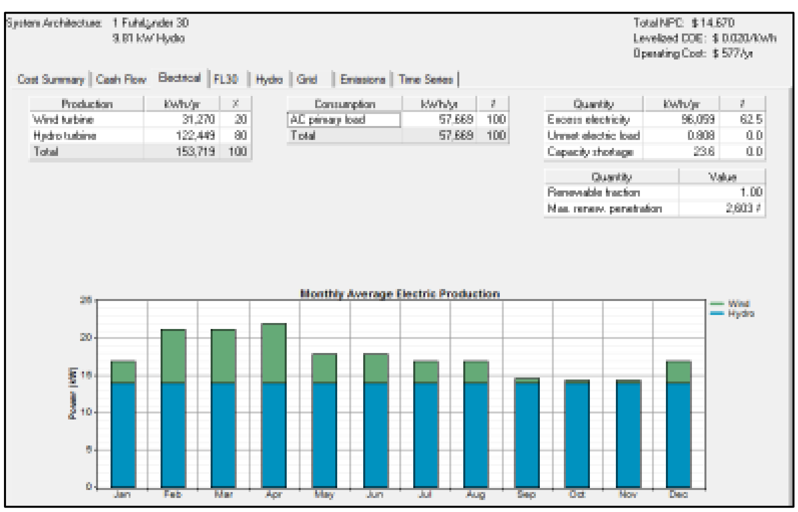

Figure 11. The realized results in case study 1

Table.3. Results of case study 1

Nominal Hydro kW	Performance Results			
	Hydro Production kWh/yr	Wind Production kWh/yr	Hydro Production %	Wind Production %
9.81	122.449	31.270	80	20
	Cost Results			
	Initial Capital ($)	Operating Cost ($/yr)	Total NPC ($)	COE ($/kWh)
	7.300	577	14.670	0.020

8.2. Case Study 2

Hydro Head = 25 m - - Design Flow Rate = 40 L/S - Hydro Turbine Efficiency = 95 % --- Hydro Head Loss = 10 %

The simulation results regarding case study 2, are given as shown in Fig.12.

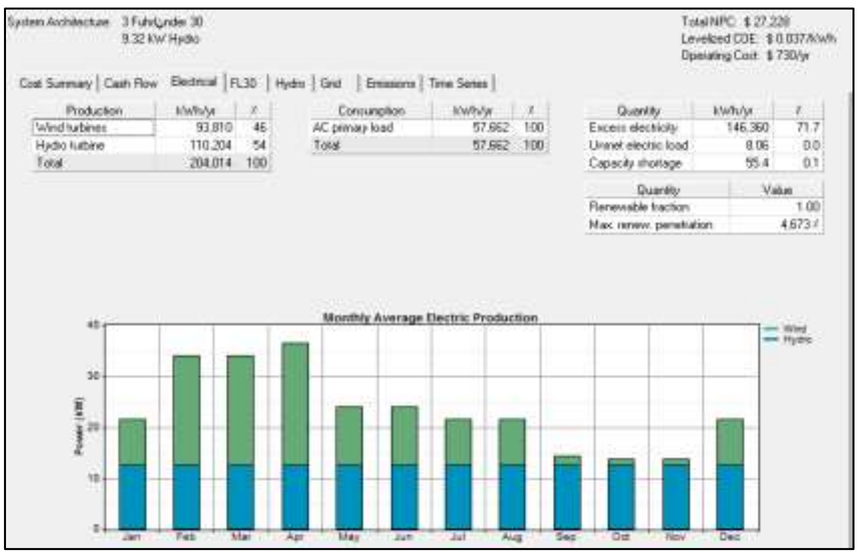

Figure 12. The realized results in case study 2

Table 5. Results of case study 2

Nominal Hydro kW	Performance Results			
	Hydro Production kWh/yr	Wind Production kWh/yr	Hydro Production %	Wind Production %
9.32	110.204	93.810	54	46
	Cost Results			
	Initial Capital ($)	Operating Cost ($/yr)	Total NPC ($)	COE ($/kWh)
	17.900	730	27.228	0.037

8.3. *Case Study 3*

Hydro Head = 25 m -- Design Flow Rate = 50 L/S ---Hydro Turbine Efficiency = 100 %-- Hydro Head Loss = 5 %

The better performance results are realized regarding case study 3, which has given the highest power production as shown in Fig.13, with respect to the chosen hydro heights.

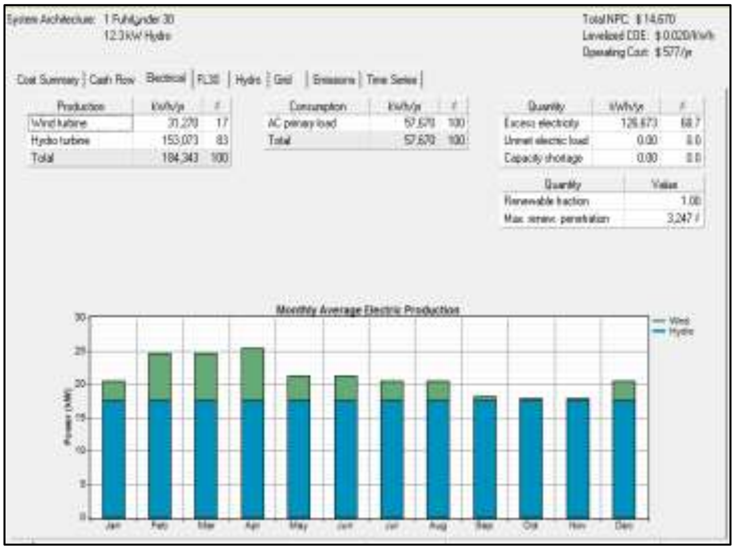

Figure 13. The realized results in case study 3

Table 6. Results of case study 3

Nominal Hydro kW	Performance Results			
	Hydro Production kWh/yr	**Wind Production kWh/yr**	**Hydro Production %**	**Wind Production %**
12.26	**153.073**	**31.270**	**83**	**17**
	Cost Results			
	Initial Capital ($)	**Operating Cost ($/yr)**	**Total NPC ($)**	**COE ($/kWh)**
	7.300	**577**	**14.670**	**0.020**

8.4. *Case Study 4*

Hydro Head = 25 m --Design Flow Rate = 50 L/S ---Hydro Turbine Efficiency = 85 % --Hydro Head Loss = 15 %

The results are realized after well simulation processes regarding case study 4 in order to reach the parameters shown in Fig.14.

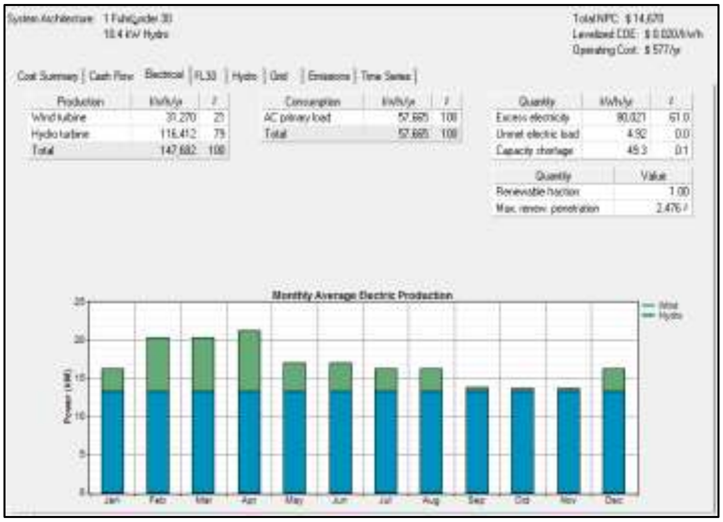

Figure 14. The realized results in case study 4

Table.7. Results of case study 4

Nominal Hydro kW	Performance Results			
	Hydro Production kWh/yr	**Wind Production kWh/yr**	**Hydro Production %**	**Wind Production %**
10.42	**116.412**	**31.270**	**79**	**21**
	Cost Results			
	Initial Capital ($)	**Operating Cost ($/yr)**	**Total NPC ($)**	**COE ($/kWh)**
	7.300	**577**	**14.670**	**0.020**

8.5. *Case Study 5*

Hydro Head = 20 m - Design Flow Rate = 50 L/S --Hydro Turbine Efficiency = 100 % --Hydro Head Loss = 15 %

The simulation results demonstrated in Fig.15 represents a critical possibility shown in case study 5.

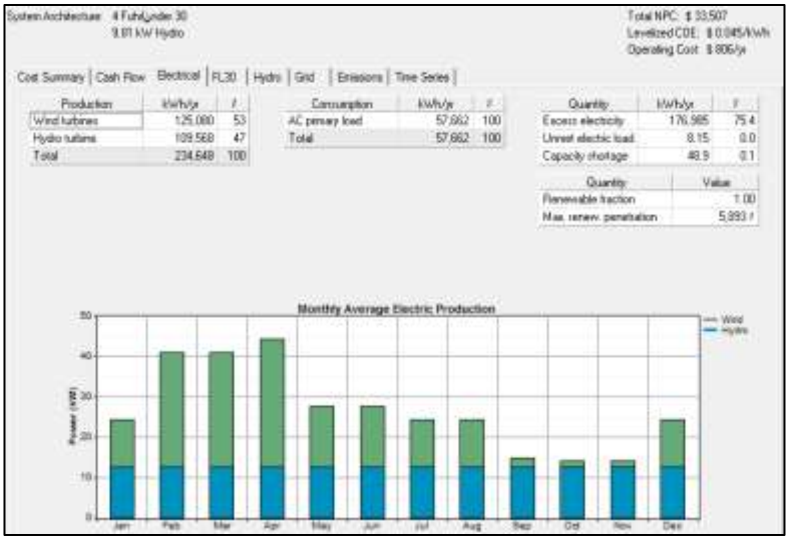

Figure 15. The realized results in case study 5

Table 8. Results of case study 5

Nominal Hydro kW	Performance Results			
	Hydro Production kWh/yr	Wind Production kWh/yr	Hydro Production %	Wind Production %
9.81	109.568	125.080	47	53
	Cost Results			
	Initial Capital ($)	Operating Cost ($/yr)	Total NPC ($)	COE ($/kWh)
	23.200	806	33.507	0.045

8.6. *Case Study 6*

Hydro Head = 20 m --Design Flow Rate = 50 L/S --Hydro Turbine Efficiency = 95 % -- Hydro Head Loss = 10 %

The last simulation results regarding case study 6 are exposed in Fig.16 that can complete performance evaluation section successfully.

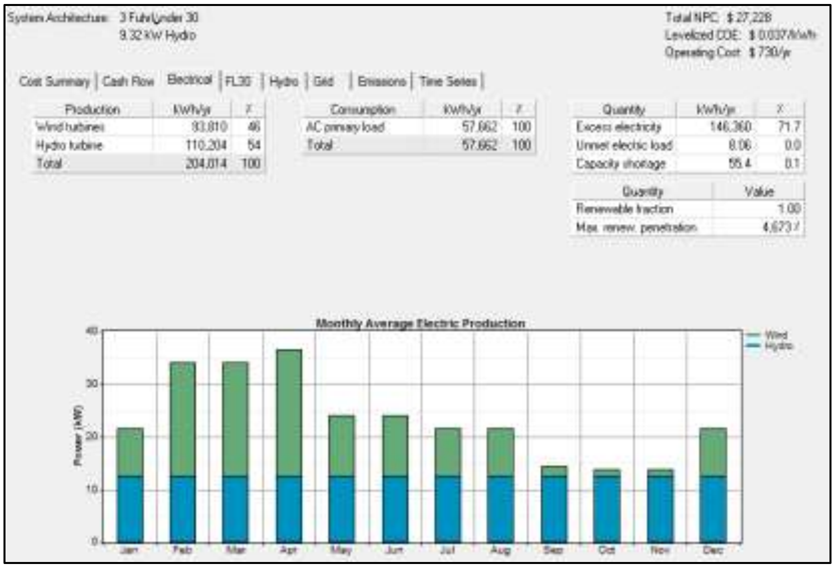

Figure 16. The realized results in case study 6

Table 9. Results of case study 6

Nominal Hydro kW	**Performance Results**			
	Hydro Production kWh/yr	**Wind Production kWh/yr**	**Hydro Production %**	**Wind Production %**
9.32	**110.204**	**93.810**	**54**	**46**
	Cost Results			
	Initial Capital ($)	**Operating Cost ($/yr)**	**Total NPC ($)**	**COE ($/kWh)**
	17.900	**730**	**27.228**	**0.037**

Furthermore, the spotlight that should pay attention is demonstrated in Table 10, which unveils the excess electricity produced in each case study. The excess electricity results inspire future extensions for more investment projects.

Table 10. Excess electricity for each case

Case No	**Excess electricity kWh/yr**	**Excess electricity %**
1	**96.059**	**62.5**
2	**146.360**	**71.7**
3	**126.673**	**68.7**
4	**90.021**	**61.0**
5	**176.985**	**75.4**
6	**146.360**	**71.7**

9. COMPARISON WITH GRID EXTENSION

A novel ultimate result is reached based on a comparison operation occurred between the stand-alone system and the breakeven grid extension with respect to the proposed hybrid power system. The comparison results delighted minds due to the negative distance values that were obtained based on the cases presented above. This means, that our proposed hybrid system without terms, is considered better and cheaper than extending power from the grid. Hereby, there exist no breakeven grid extensions curves are shown as Fig.1, (SAMEER S. AL-JUBOORI, ALI H. MUTLAG, 2014). The grid extension is modeled in HOMER as shown in Fig.17.

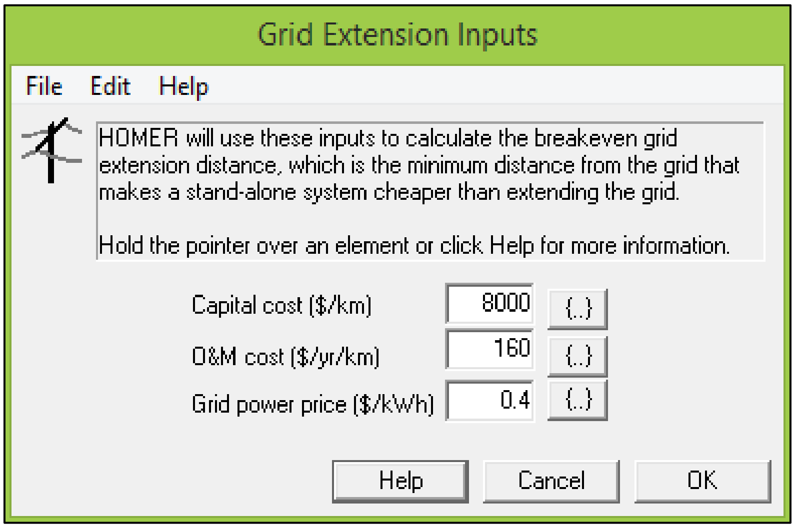

Figure 17. Grid extension input

Furthermore, it is intended to show the negative breakeven grid extension distances with respect to each proposed case as shown in Table 16.

Table 16. Stand-alone Vs Grid extension results

Case No	Gird extension distance (Km)
1	**-27.9**
2	**-26.6**
3	**-27.9**
4	**-27.9**
5	**-26.0**
6	**-26.6**

Table 16, confirms that the distances from the proposed location to the hydro power station for the chosen cases are always less than zero. Under this act, our proposed power system as an investment is considered better and cheaper than the breakeven grid extension.

For more confirmation and clarity, the optimum result concerning system performance among the six chosen cases with respect to power production factors, is shown uniformly in Table 17.

Table 17. Optimum performance results

<table>
<tr><th>Hydro Head (m)</th><th>Design Flow Rate (L/S)</th><th>Hydro Turbine Efficiency (%)</th><th>Hydro Head Loss (%)</th></tr>
<tr><td>25</td><td>50</td><td>100</td><td>5</td></tr>
<tr><td>Nominal hydro power kW</td><td>Hydro power in percentage</td><td>Wind power in percentage</td><td>Grid extension distance (km)</td></tr>
<tr><td rowspan="3">12.26</td><td>80%</td><td>17%</td><td rowspan="3">-27.9</td></tr>
<tr><td>Hydro power kWh/yr</td><td>Wind power kWh/yr</td></tr>
<tr><td>153.073</td><td>31.270</td></tr>
</table>

Finally, the optimum result regarding cost limitations of the power system among the proposed cases with respect to power production factors is shown in Table 18.

Table 18. Optimum cost results.

Hydro Head (m)	Design Flow Rate (L/S)	Hydro Turbine Efficiency (%)	Hydro Head Loss (%)
25	50	100	5
Initial Capital ($)	**Operating Cost ($ / yr)**	**Total Net Price Cost NPC ($)**	**Cost of Energy (COE)**
7.300	577	14.670	0.020

10. CONCLUSIONS

In this paper, a novel design of a hybrid power system is presented. The obtained results satisfy the theoretical analysis given by HOMER. The proposed idea solved the natural geographical formalization impairments that might be encountered in some specific locations. In addition, several cases were studied in order to confirm and show the impact of hydroelectric power plant considerations on the performance and cost of power systems. In order to simplify the demonstration of the realized results, it is intended to order the results as follows:

1. A robust hybrid power system is constructed by using hydroelectric power station and wind turbine module to produce the required power for the specified location.
2. There exist several considerations can dominate the nominal hydro power production.
3. As a fulfillment, four considerations of hydroelectric power station were chosen in order to emphasize the considerable dependency of system performance / cost on the specification of hydroelectric power station.
4. In case study 3, the maximum power was produced in cheapest cost.

5. The cheapest costs were reported as cost of energy COE around 0.020 $/kWh, with respect to initial capital of 7.300 $, operating cost of 577 $/yr, total net price cost of 14.670 $.
6. It can be stated in accordance with the other case studies that a change in Hydro head loss among the options specified by (5, 10, 15) % does not change the nominal hydro power. However it effects considerably on the percentage amount of produced power by the hybrid system components as clarified in the cases 1&3.
7. A tiny alteration in the possible options for Hydro head, Design flow rate, and Hydro turbine efficiency can realize different nominal hydro power.
8. The dependency on the proposed power system in the specified location is considered cheaper than extending power form the grid due to the negative distances that are realized from comparison operation.
9. The realized excess power inspires the future to cover larger rural areas.
10. Finally, the control system is designed in order to supervise water flow ratio of the Tank unit, knowing that any lack in Tank water in the worst cases can effect for a little bit on the amount of the produced power, that is the whole hypothesis does not make sense due to the plentiful excess power production.

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