# Simulation, Optimization, and Analysis Approach of Microgrid Systems

Saqib Ali
Department of electrical engineering
NFC-IET Multan
Multan, Pakistan
Saqib.ali@nfciet.edu.pk

**Abstract—Sources are classified into two depending upon the factor of reviving. These sources, which cannot be revived into their original shape once they are consumed, are considered as nonrenewable energy resources, i.e., (coal, fuel) Moreover, those energy resources which are revivable to the original condition even after being consumed are known as renewable energy resources, i.e., (wind, solar, hydel) Renewable energy is a cost-effective way to generate clean and green electrical energy Now a day's majority of the countries are paying heed to energy generation from RES Pakistan is mostly relying on conventional energy resources which are mostly nonrenewable in nature coal, fuel is one of the major resources, and with the advent of time their prices are increasing on the other hand RES have great potential in the country with the deployment of RES greater reliability and an effective power system can be obtained In this thesis, a similar concept is being used and a hybrid power system is proposed which is composed of intermixing of renewable and nonrenewable sources The Source side is composed of solar, wind, fuel cells which will be used in an optimal manner to serve load The goal is to provide an economical, reliable, uninterruptable power supply. This is achieved by optimal controller (PI, PD, PID, FOPID) Optimization techniques are applied to the controllers to achieve the desired results. Advanced algorithms (Particle swarm optimization, Flower Pollination Algorithm) will be used to extract the desired output from the controller Detailed comparison in the form of tables and results will be provided, which will highlight the efficiency of the proposed system.**

***Keywords—distributed generation; demand-side management; hybrid power system; micro grid; renewable energy resources; supply-side management***

## I. INTRODUCTION

The electric power system created the revolution decades ago at domestic, commercial, as well as industrial levels. In the modern era, technology is becoming advanced and smart that requires an intelligent type of power system which is possible by using different types of advanced techniques and tools for the transformation of a traditional grid into a smart (micro) grid [1]. The task of provision of proper and affordable electricity to everyone is a challenging task. Many people are forced to survive without electricity, and small regional-based energy production is crucial to ensure continuous power supply, especially to those users to which the electricity cut down is unaffordable or their location is too far that electricity provisions to those areas become immensely expensive. However, the population suffering from power outages has improved slightly after a few years of dedicated efforts of researchers to develop such techniques and tools to improve the generation, transmission, distribution, and utilization sectors of the electrical power system [2].

The researchers have worked a lot on renewable energy resources (RERs) that are outside the grid system [3]. These RERs are growing rapidly. Renewable energy resources including solar Photo Voltic Cell (PVC), wind, solar thermal, biomass, geothermal, and big and small hydropower plants can provide stable and inexpensive energy to all people regardless of where they are. These sources are clean too, they are ubiquitous and have no political or local boundaries, and are readily usable. These sources are of a distribution nature and thus they can be paired with any grid system with both mixed and single sources. The size measurement methods of hybrid power systems ensure the reliability of power and the low cost of the system [4].

Continuous power supply to the consumers is ensured by using multiple power sources synchronized together, that is, a hybrid power system. This type of system contains at least two power sources and can have more even. These power sources could be solar PVC, and wind energy with a fuel cell with battery backup in our proposed study [5].

According to research on the market of hybrid systems carried out in 2019, the use of this technology is expected to rise extraordinarily, roughly from 500 million USD in 2017 to 850 million USD in 2024 [6]. These statistics depict that a hybrid system is being deployed worldwide although the pace is a little low currently. The reason for such strong emergence of hybrid systems includes high efficiency, high reliability, less expenses, and environmental friendliness [7].

Another reason to the use of RERs increased day by day is a continuous and gradual increment of almost 8 percent in the price of electricity each year. This rise in the cost of electricity further affects the price of coal and the costs of coal increases by 10 percent every year. It is possible that soon, the novel strategic expenses further increase the prices of coal, and hence there will be a substantial jump in the costs of coal-based electric supply. The power expenses can be reduced using reusable resources since they depend upon natural resources [8]. By shifting to the use of distributive power resources, the energy expenses in the future can be made steady and balanced [9].

Electrical energy in the typical AC network is likely received from a spacious hydropower system and thermal power system. In the center of the energy production network, the alternator (synchronous generator) can rotate at a set speed for producing a frequency of 50hz, AC or 60Hz AC, and its output power is also controllable [10]. However, in our small RERs based production is dependent upon renewable static sources. The renewable source's optimum output power is not

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controllable because of the stochastic character of the rest. As a result, backup of batteries and nonrenewable production may be necessary to uphold the balance of power in network under varying RERs [11].

To fulfill the needs of atmosphere protection and electricity requirements, the world is shifting toward reusable energy production for the past few years. Since both solar and wind resources are interdependent, therefore, in those places where there are no power reserves, the best choice for the providence of smaller electric loads is the combination of solar and wind along with a fuel cell (if possible). In this case, if the weather is cloudy and the sun is not visible, then a lot of wind is present in this weather [12].

These RERs are controlled by different types of controllers, sensors, and the use of modern algorithms to measure parameters in real-time, allowing the system to respond quickly to changes in the environment as they are implemented [13]. This means that both systems' features are adopted by the distributed system when nodes can communicate, and a coherent control approach is created. The utilization of modern techniques, controllers, and algorithms improves the electrical power system control topology and eliminates different types of complex requirements [14].

The excessive use of nonrenewable energy resources generates environmental issues. That is why the power system is being moved towards the use of RERs [15]. The main contribution to the injection of renewable-based power in the system is the transmission part of the existing power systems. The grid efficiency is decreased due to the line losses present in the transmission system. The major factor is the uncontrolled electrical power consumption from the traditional grids [16]. One of the most critical problems in the electric power system is that approximately 1.2 billion people do not have an electricity facility. Most of the people in this figure lived rural or remote/separate communities. To provide electricity to these communities, economic factors are involved majorly in terms of finance, ecological, societal, etc. [17].

For these types of areas, distributed generations are the best remedy. With the use of power converters, these RERs are linked together to the nearest distribution system. This type of generation also facilitates the local and other localized loads to develop a sustainable electrical distribution system [18].

The most appealing element of a microgrid is its small size ranging from 50 kW to multiple MW capacity. It is the most feasible solution to provide electricity to these remote areas easily. Moreover, the microgrids are of different types and sizes varying from AC/DC and small to large in terms of electrical power [19]. The type and capacity of the load will decide that either the microgrid is AC or DC and of what size. The power and electronic converters are used to connect these RERs to the loads. These converters are used to manage the disturbances and provide a constant output voltage. The major issue as highlighted earlier is the constant provision of the range of voltage to the load. In simple words, it has the supply of sustainable and stable electricity in the presence of various RERs to optimize the microgrid stability concerns [20]. A lot of control and optimized techniques is being developed in the last ten years that can be seen in the literature on the microgrid.

The microgrid comprises sources that can be renewable or nonrenewable, loads, and storage. The electronic converter plays a vital role in designing the microgrid. Two converters are utilized in microgrids [35]. The first one is the buck energy converter which makes the load capacity to get electricity from the microgrid and the second one is the boost energy converter which provides the energy to the microgrid. Nodes are provided by the bidirectional energy converter charge and discharge from and into the microgrids, respectively [37].

The main purpose and contribution of this paper are to further explore the ideas presented in the above-mentioned research on microgrids. Although there is some research previously done in this field. However, this research is carried out from the point of view of hybridizing the renewable energy resources RERs, either solar and wind generators, etc., However, no research has been done on the potential benefits of using the hybrid model of solar-wind-fuel cell systems. In this research work, our contributions are to design a solar PV, wind, and fuel cell-based 60 kW microgrid. Particle Swarm Optimization (PSO), as well as Flower Pollination Algorithm (FPA), are utilized. These algorithms are used to tune the different parameters of various controllers (i.e., I, PI, PD, PID, FOPID, and SMC). These considered controllers along with the considered algorithms have neither been previously used in the literature to optimize the power. The comparison is being done along with the conventional controllers. Integral Square Error is used as the objective function that is being minimized using the considered algorithms. The best control method is also analyzed by using a comparative study. A switching algorithm is also introduced for the switching of renewable energy resources RERs, the proposed algorithms (FPA and PSO) being used in this research providing high flexibility and reliability, fast convergence, ease of implementation, strong robustness, local solution exploration stability, ability to handle the objective function, and the capability of being combined with other optimization algorithms.

## II. METHODOLOGY

When power loads and supply are changeable, the micro grid's primary control challenge involves maintaining power balance. The major way of maintaining the system power balance must be by supply management, to prevent the load from becoming susceptible to changes in renewable energy generation. To reduce the running expenses of the microgrid, the supply side management system plans the sources that are present in it. The supply-side topology control method ensures that the use of renewable energy is maximized since the fuel price of the energy source is insignificant [58]. Renewable energies provide the base load and excess energy is used to charge the backup storage. If there is a shortage of energy from renewable sources, energy is taken from a buffer storage. The backup generation will come online when storage devices are exhausted due to a long-term shortage of renewable energy. Several control topologies can be used to control the resources present in the microgrid. The main criterion for selecting a control technique is its ability to perform source scheduling according to source and load control laws. The control technology chosen must be suitable for maintaining modularity and reliability in a distributed network of systems. In addition, it must be reliable and economical to implement to help increase the economics of the network.

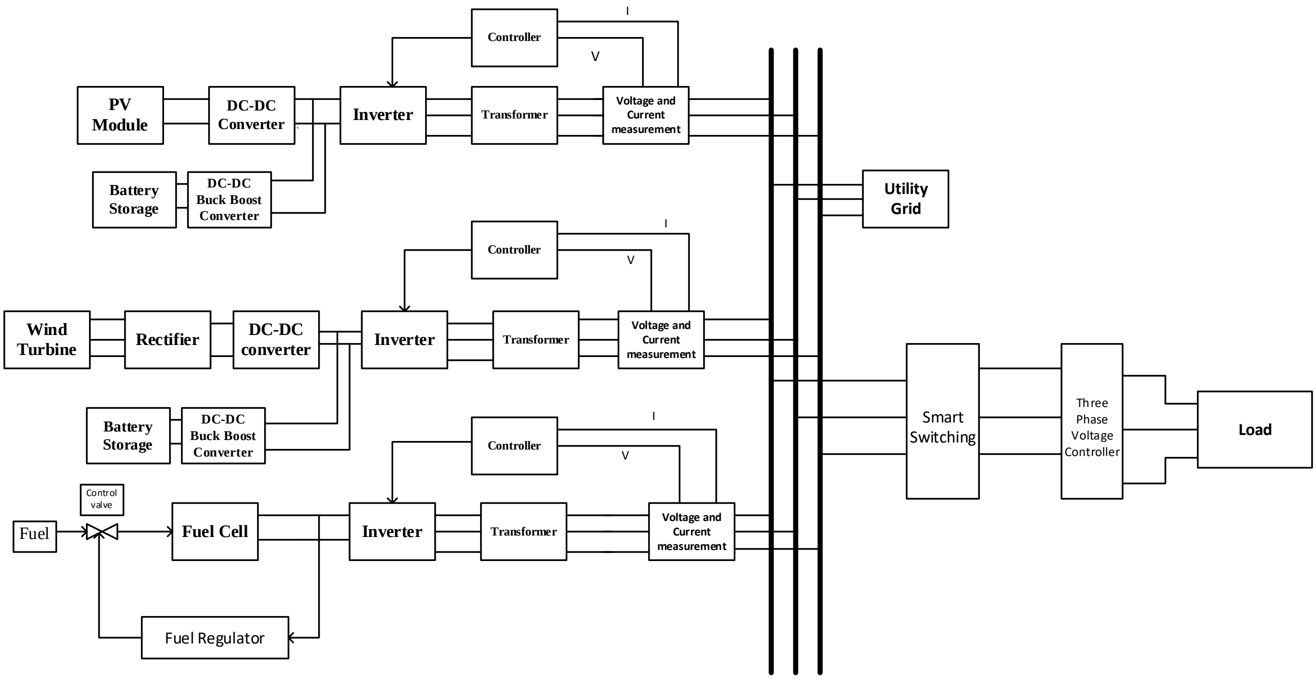


Figure 1: Block diagram of micro-grid

*A. A. GENERATION SOURCES*

*1) PV array*

Figure 1 shows that the three sources are connected and interlinked at the AC bus. In a PV array, 23 strings are connected in parallel and there are 5 connected modules per string in series. The maximum power from one cell that can be extracted is 305.226, from that we have a PV array having a capacity of 35kW from that we just extracted the power of 20kW. MPPT technique has been implemented on the PV array and then there are two types of converters that have been used. The first converter that has been used is the Buck-Boost converter [21] that is attached to the storage battery. The buck converter is used to store the power in batteries while in the absence of power from the PV array that power is extracted through boost and fed to the inverter for the demand of the load. The dc-dc boost converter is used in the next stage of that wing and it just levels up the voltage produced from the array.

*2) Wind Turbine*

The wind turbine is the second source that has been connected to the microgrid. The generation of a wind turbine is 20KW having a power factor of 0.8, The reactive power that has been produced by the wind turbine is around 12KW. The speed of wind is not nominal or ideal. The wind speed is variable just like in the real-life case. The three-phase Permanent Magnet Synchronous Machine (PMSG) is connected to a wind turbine [22]. In the next stage, the generation of a wind turbine is rectified into DC. The reason for converting the ac into dc is to smoothen the power and store the power in batteries with a Buck-Boost converter and it can be used in the absence of power from the source.

*3) Fuel Cell*

There are many types of fuel cells but due to their efficiency, Solid Oxide Fuel-cells (SOFC) are used in this model. The SOFC converts chemical energy into electrical energy directly and its conversion efficiency is 65% [23]. The main advantage of SOFC is that its byproduct is high-temperature steam, which is used for different purposes. Their disadvantage is its slow response time. DC power is fed to a DC bus. DC bus has a constant DC voltage, because the inverters operate with the constant input voltage.

To achieve an uninterruptable and reliable power supply, renewable and nonrenewable energy sources are combined in a synchronized manner and a hybrid system is designed. Amongst all sources, photovoltaic is the most effective that is why it is acting as a main source in the proposed work. Each source has its specific criteria, moreover they are combined to get an uninterruptable power supply.

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### B. POWER MANAGEMENT SYSTEM OF PROPOSED HYBRID MICROGRID

The main problem with HPS is power distribution. Due to a large number of renewable and nonrenewable sources, their power distribution can lead to problems with power quality and stability. To ensure the transmission of continuous, stable, and high-quality performance, a proper power management system (PMS) is needed. In the literature, a power management system is proposed in [64] for a standalone hybrid power system. PV and wind are the primary sources, keeping FC and battery bank as a backup. In [24], the proposed PMS FC will suppress the fluctuations caused by PV/Wind. In [25], the authors proposed the PMS for wind, FC, and SC. First wind will provide its power, then FC and SC if do not meet the requirement of the wind.

The difference between load and generation is given as

$$P_{diff} = P_{WT} + P_{PV} - P_{load} \quad (1)$$

$$P_{load} = P_{res} \quad (2)$$

Where Pres is the residential load. The difference might be positive or negative. There are two modes depending on the difference in power:

- Positive (Surplus power),
- Negative (Deficient power)

*1) Model 1 (Surplus Power)*

When PV production and the production of a wind turbine are greater than the load, the excess energy is released to the batteries for charging. If excess electricity is still available, it is not used supercapacitors for being charged. The balanced equation can be written as

$$P_{PV} + P_{WT} = P_{Load} + P_{sc-c} + P_{batt-c}, \quad P_{diff} > 0 \quad (3),$$

Where $P_{sc-c}$ and $P_{batt-c}$ are the powers required for charging the battery and super-capacitor.

*2) Mode (2) (Poor Performance)*

When there is deficient power, i.e., PV production is less than the load, then

The wind turbine is available to generate energy and compensate for the deficiencies.

The battery will deliver power and try to overcome it.

If the battery fails, then SC tries to deplete the deficiency of power by providing power.

If SC fails to compensate for the power, the fuel cell will deliver power and try to overcome the deficiency.

If the shortage persists, the electricity is drawn from the public power grid.

The overall balanced equation for deficient power is given as

$$\left.\begin{array}{l} P_{PV} + P_{FC} + P_{WT} = P_{load}, t \neq peakhour \\ P_{PV} + P_{FC} + P_{WT} + P_{Grid} = P_{load}, t = peakhour \end{array}\right\} P_{diff} < 0 \quad (4)$$

### C. Objective function

The integral squared error (ISE) objective function is minimized in all optimization techniques. It is possible to define ISE this way:

$$ISE = \int_0^{\infty} [e(t)]^2 dt \quad (5)$$

ISE for all approaches that have been optimized;

(I-FPA) ISE = 1.522 e 12

(I-PSO) ISE = 1.475 e 12

(PI-FPA) ISE = 1.856 e 12

(PI-PSO) ISE = 1.985 e 12

(PD-FPA) ISE = 2.344 e 13

(PD-PSO) ISE = 2.0543 e 13

(PID-FPA) ISE = 1.9856 e 12

(PID-PSO) ISE = 1.8132 e 12

(FOPI-FPA) ISE = 2.785 e 12

(FOPI-PSO) ISE = 3.9454 e 12

(FOPID-FPA) ISE = 5.0162 e 13

(FOPID-PSO) ISE = 2.098 e 13

(SMC) ISE = 1.551 e 12

*D. Implementation of Algorithm*

- The algorithms have minimized the objective function subject to the following constraints
- Frequency constraint: The actual value of the frequency must be within 0.8% of the desired frequency.
- Another constraint for the designed micro-grid system is:
- Voltage (L-L) constraint: The actual value of the voltage (L-L) must be within 6% of the desired voltage (L-L).
- 20 kilo Watt < Power generation < 60 kilo Watts

The I, PI, I, PID, PD, FOPID, FOPI as well as SMC controllers have been optimized using Genetic Methods and Particle Swarm Optimization algorithms. All controllers with both algorithms and their control settings have also been examined using a comparative analysis. For both algorithms, 30 iterations are set on all controllers. The Integral Square Error is the goal function for both methods (ISE). Both techniques have utilized the following upper and lower limits for tuning parameters:

Gain values inside the border limitations were selected by FPA and PSO algorithms to identify the best path. The FPA algorithm has also tested 1500 permutations of tuning parameters to get the greatest gain value with the smallest goal function.

*E. Proposed Flowchart*

In our proposed work, via using controllers, the objective functions are minimized. For this presented case, the objective function is an integral squared error. Using intelligent algorithms, the gain of the controller is controlled and the required results are generated. The algorithms which are controlling the gain of the controllers are Flower Pollination Algorithm and Particle Swarm Optimization. Controllers are optimized using these algorithms and their respective gains are compared head-to-head. Figure 2 shows the flow of the proposed research.

The above figure shows how the objective function is minimized by the controllers using these algorithms' flower pollination algorithm and particle swarm optimization control, gains of the mentioned controllers, and the desired output is achieved.

Table 1: Gains of all controllers are constrained within certain limitations.

| Gains | Lower bound | Upper bound |
|---|---|---|
| Kp | 880 | 1250 |
| Ki | 3750 | 4150 |
| Kd | 400 | 700 |

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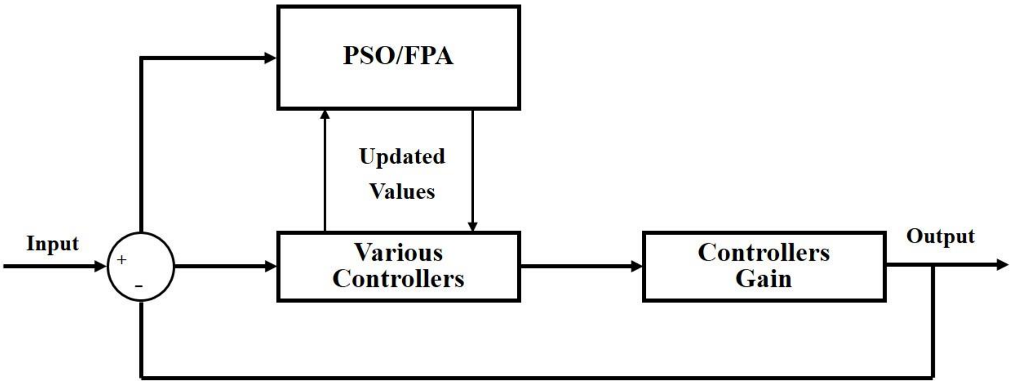


Figure 2: Flow of proposed Micro-grid

## III. Simulations and Results

These simulation findings are included in this chapter, which includes the hybrid Micro-proposed grid's power management system (PMS). Each source wing's normal operation results are shown first, followed by a discussion on how the proposed hybrid microgrid manages its power supply. According to IEEE standards, all findings of the simulated model are within the IEEE standard limitations.

According to the preceding sections, three sources are included in the proposed hybrid Micro-grid. This hybrid Micro-grid PV power system relies on solar irradiance and air temperature to generate 20 KW of power as its principal source, however, the optimum circumstance of irradiance and temperature has been taken in this suggested approach. Figure 3 shows the reference real power of 20KW and the output real power of the PV array.

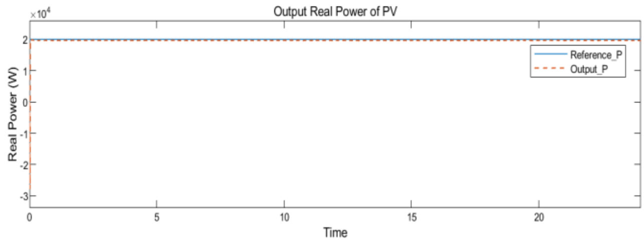


Figure 3: Output real power of PV with reference

The peak-to-peak voltage VP-P is the voltage waveform measured from the top of the waveform (called the crest) to the bottom of the waveform (called the voltage drop). Therefore, peak-to-peak voltage is only the entire vertical length of the top-to-bottom voltage waveform, Vp-p of the PV module is shown in Figure 4.

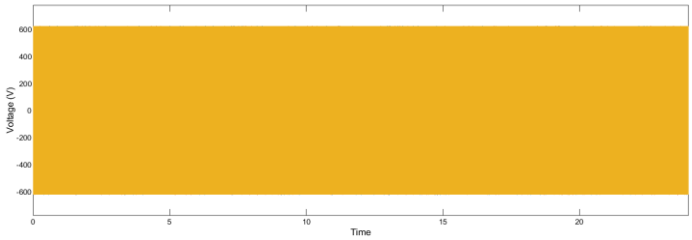


Figure 4: Vp-p of PV source

In the planned Micro-grid, a wind turbine would serve as a secondary power source. In comparison with other controllers, the sliding mode controller has the least steady-state error and the shortest settling time among the optimal controllers and algorithms. Other controllers' output contains transients. As a supplemental source for the hybrid Micro-grid, the wind turbine, Figure 5 shows the actual power output of the system, which is 20 kilowatts.

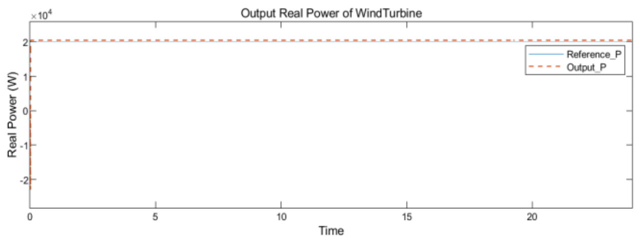

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Figure 5: Real output power of Wind with reference

Here the max voltage OR peak voltage at positive half cycle and the max voltage OR peak voltage at negative half cycle is called peak-to-peak voltage. The peak-to-peak voltage of the wind turbine is shown in Figure 6.

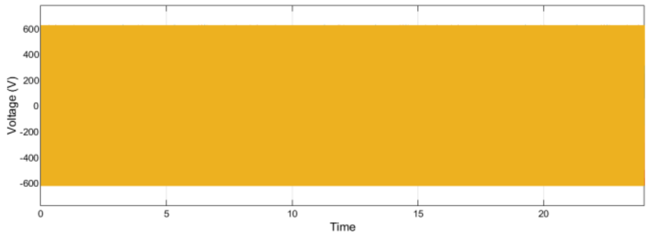


Figure 6: Vp-p of wind turbine

The planned hybrid Micro-third grid's power source is a fuel cell. If the load demand exceeds the production of primary and secondary wind turbines, then the fuel cell is turned on to give electricity to the load, according to a smart algorithm, the fuel flow rate controller of the fuel cell has been installed PID to controller flow rate of fuel towards the fuel cell by detecting the changing current flow rate of fuel in the fuel cell. The transients of a system may be controlled by sensing the current and adjusting the flow rate of the control. The Micro-inverter grid's control features a sliding mode control, resulting in optimal output power. Figure 7 depicts the fuel cell's real-world power generating capacity of 20 kilowatts (KW).

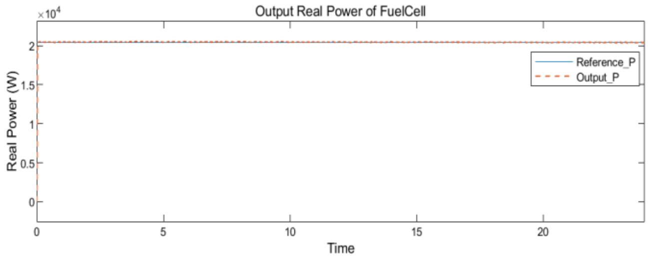


Figure 7: Real output power of fuel cell with reference

The Vp-p of the PV module has been represented in figure 8.

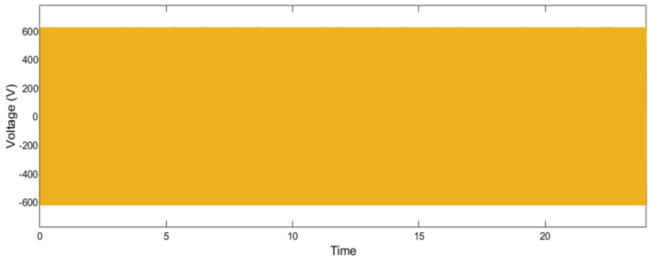


Figure 8: Vp-p of fuel cell

The load is a variable whose supply and demand fluctuate on an hourly basis. The load coupled to the AC bus can be called the variable, this is because in an AC bus the load demands 15 KW and fluctuates during the day and reaches its highest demand of 58 KW, which necessitates the use of a smart switching system. Figure 9 depicts the demand for and supply of load over time.

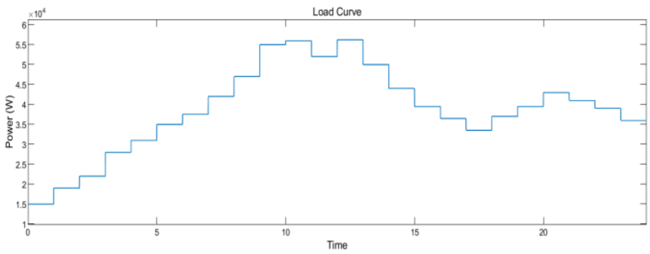


Figure 9: Load Curve of the load

The frequency is a critical system characteristic, and variations in load demand have an impact on it as well as on the frequency. This reveals that the load is changing, which is why a frequency controller is needed to keep the system's frequency stable, as transients in the frequency indicate a changing load. After 0. 09 seconds of inactivity, the system is stable. Variations at that point are allowed to be as low as 1% of the planned frequency, which is in line with the limitations. An illustration of the system's frequency may be seen in Figure 10.

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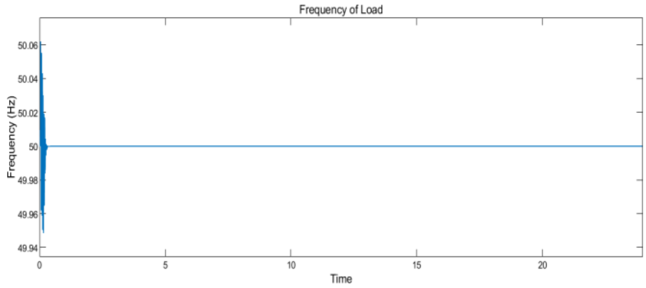
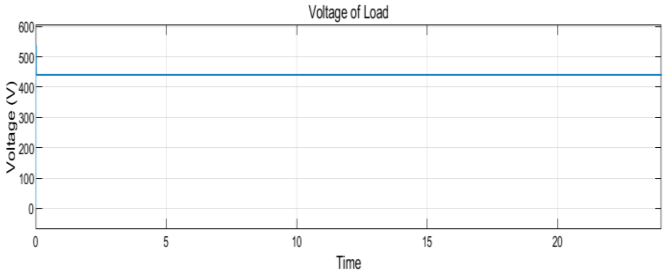



Figure 10: Load Frequency

The above figure shows that when the grid is attached to the load, for some instance, there are fluctuations in the system. However after some time the frequency is under the desired limit 50Hz.

Figure 11: represents the voltage of the load.




Time (hrs.)

Figure 11: Voltage of Load

In Table 2, for all controllers applying both approaches, the optimal gain values and controller settings are shown.

The performance of optimized controllers can be analyzed through the mentioned algorithms. Table 3 shows the outcomes of all modified controllers, with increase ( positive sign) or reduction ( negative sign) as shown below.

Table 2: Control parameters

| Controller | Rise Time (s) $10^{-4}$ | Peak Time (s) $10^{-4}$ | Settling Time (s) $10^{-4}$ |
|---|---|---|---|
| I-FPA | 15 | 369 | 747 |
| I-PSO | 10 | 369 | 752 |
| PI-FPA | 19 | 259 | 4356 |
| PI-PSO | 19 | 259 | 4551 |
| PD-FPA | 31 | 261 | Nan |
| PD-PSO | 31 | 264 | Nan |
| PID-FPA | 19 | 262 | 4544 |
| PID-PSO | 20 | 263 | 4545 |
| FOPID-FPA | 90 | 387 | Nan |
| FOPID-PSO | 07 | 241 | Nan |
| FOPI-FPA | 19 | 261 | 4749 |
| FOPI-PSO | 31 | 268 | 5987 |
| SMC (two loop) | 20 | 166 | 267 |

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Table 3 Performance index of optimized controllers

| Controller | Rise Time (%) | Peak Time (%) | Settling Time (%) |
|---|---|---|---|
| PID-FPA | -5.26 | 0.39 | 0.03 |
| PID-PSO | 0.98 | 0.99 | 0.99 |
| PI-FPA | -5.26 | 0 | 4.15 |
| PI-PSO | -2.52 | 1.140 | -0.13 |
| PD-FPA | -42.10 | -0.49 | - |
| PD-PSO | -41.20 | -0.39 | - |
| I-FPA | 26.31 | -42 | 83.56 |
| I-PSO | 22.63 | -41 | 83.45 |
| FOPID-FPA | -368.42 | -1378 | - |
| FOPID-PSO | -268.42 | 8.4 | - |
| FOPI-FPA | -15.78 | -1.90 | -4.489 |
| FOPI-PSO | -12.10 | 0.8 | -31.7 |
| SMC-FPA | -374.31 | -1386 | -5.73 |
| SMC-PSO | -279.56 | -54 | -33.6 |

The rising time of the PID-FPA is decreased by -5.26% and the rising time of PID-PSO is increased by 0.98%. The trend of rising time shows that FPA shows better results compared to PSO. The best result is shown by SMC. The peak time of the PID-FPA is increased by 0.39% and the rising time of PID-PSO is increased by 0.99%. The trend of peak time shows that FPA shows better results compared to PSO. The best result is shown by SMC as presented. The settling time of the PID-FPA is increased by 0.03% and the rising time of PID-PSO is increased by 0.99%. The trend of settling time shows that FPA shows better results compared to PSO. The best result is shown by SMC. The time constant of the PID-FPA is decreased by 12.6% and the rising time of PID-PSO is increased by 0.98%. The trend of time constant shows that FPA shows better results in all controllers compared to PSO. The best result is shown by SMC as presented. The Steady State Error of the PID-FPA is decreased by 41.024% and the rising time of PID-PSO is decreased by 39.29%. The trend of Steady State Error shows that FPA shows better results in all controllers compared to PSO. The best result is shown by SMC as presented.

## IV. CONCLUSION AND FUTURE WORK

A general and brief introductory review of the thesis is analyzed, The importance of hybrid Micro-grid for isolated areas and the role of renewable generation in the real world are discussed mainly dependent on the small power source of the renewable system, electrical power from Micro-grid is more costly as compared with grid electrical power while these power sources had high production expenses Therefore, a Micro-grid is nowadays constrained for niche purposes like isolated energy provided for financial purposes The dimensions of the Micro-grid which is regarded in the thesis are arranged of 10-60 kilowatts, with the load that is situated within 5 km of the power supplying source Micro-grid contains a renewable power source, non-renewable power source, and backup storage is also integrated into the generation to smoothen the variations and increase the stability of supply Sources that exist in Micro-grid generate varying frequency ac output or a varying voltage dc Electronic converters are used for that reason necessary for interfacing the power sources with a constant frequency network Electronic converters are also utilized to interconnect load with the network The interfacing converter at the load side demonstrates stable characters of power, performing like negative-impedance in the network. The key Micro-grid control problem is the management of the balancing power in the network in the existence of variable power loads or supply Source-side control topology has been implemented easier if the sources are controlled from a central point One main disadvantage of a central controller is the decrease in network reliability through the decentralized topology of control, every power source can be controlled separately which depends on the local quantity It can be seen that decentralized control, centralized control, or distributed control do not have the characteristics of the ideal control topology of the Micro-grid The distribute hybrid control is that is why used because it satisfies the criterion of selection and can achieve higher efficiency without redundant controllers or communication connections. Flower Pollination Algorithm and PSO have been used for tuning parameters of all controllers, The detailed process for the implementation of both algorithms is provided in detail Flower Pollination Algorithm has used 1500 combinations and the PSO algorithm has used 900 combinations to determine the best tuning parameters of the controller the system constraints and the objective function have been defined SMC, FOPID, and PID controllers used in this research have also been defined The detailed explanation of the function and control of every load and source wing in the proposed hybrid Micro-grid power management is the main problem in the Micro-grid as described The function of each source wing is described separately and the interconnection of source wings with backup lines is demonstrated The behavior of the system in the backup line and the function of the backup line is explained in this section Finally, a detailed explanation of the power management system is elaborated .

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