# The Engineering Process Design for a Dual-Axes Solar Power Generating System

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**Abstract:- Detailed technical feasibility study can be achieved with effective process design of a product or system. The tool has the capacity of enhancing the profitability as well as improving the productivity in the arears of design, construction/fabrication of equipment, engineering facilities or devices to specification and standards. This study aimed at the development of engineering process design for a dual axes solar power generating system. The method analyses the process design concept used in the production which involves: process selection, operation determination, and product design and analysis. The results obtained revealed that the dual-axes solar power generating system has twenty-two (22) parts assembled together in ten (10) identified major assemblies, out of which thirteen could be fabricated in the local workshop, while are to be procured as specified from the market. The study presents a viable, and economically feasible techniques for the manufacture of the dual-axes solar power generating system.**

***Keywords:-*** *Design Process, Product Analysis, Process Selection, Product Determination, Dual Axes Solar Power System, Components.*

## I. INTRODUCTION

Solar power system has contributed significantly to the provision of safe and affordable energy needed to power several electrical infrastructures in any economy. Amidst the typical sustainable energy sources, solar energy system offers a huge prospect for the generation of electric power, capable of ensuring a significant fraction of the electrical energy requirements of the planet [1] This alternate source of power is constantly achieving admirable fame especially since the discovery of fossil fuel limitations for sustainable energy has generated much research interest in many countries of the world in line with the Sustainable Development Goal [2]. The abundance of solar energy in the template zones suggests a concerted effort and investment in facilities for conversion of the sustainable source to valuable energy for several uses. A productive and sustainable product design and process development are complex acts that are multifactorial. Factor such as cost, layout of plant and equipment requirement, skill. Health, safety, and type of production.

### *A. Process Design*

Process design is a general term for a specialised planning procedure for manufacturing or service operations that integrates production service location and capacity decisions with subsequent layout, scheduling, and execution action by specifying the essential sequence of the production phases. [2]. According to [3] further explained that process design can be the design of new facilities or it can be the modification or expansion of existing facilities. The design process starts with an idea and concludes with manufacturing and construction plans. Equipment design is distinct from process design, which is conceptually closer to unit operation design. Many unit operations are frequently included in processes. [4] revealed that process design manages the production process's combination of machines, equipment, and materials. [5] noted that the process and product design's primary goal is to increase product quality and meet consumer wants. It is critical to emphasize that, while businesses must maximize profits, the time lag between the design process and actual production is lengthy, resulting in higher costs. As a result, the overall assessment of design effectiveness should include the element of product quality as a primary goal. The three main steps of process design are: product analysis process selection and operation determination [6].

### *B Product Analysis*

Product analysis is an excellent exercise to conduct before filing a product design and/or development technology for a patent [7]. The main output of product analysis is the product specification. A lot of decisions such as the purchase of materials, selection of equipment, assignment of workers, and the size and layout of the production facility depend on the product specification made [8]. The breaking down of the product into its components to identify the components and their relations to each other is known as product analysis [4].

### *C. Process Selection*

This may be considered as a series of decisions encompassing the theoretical feasibility of making the product, the general nature of the processing style, the specific equipment to be employed, and the specific routine through which the product must flow (9). There are four categories by which process selection decisions are made: major technological choice, minor technological choice, specific components choice, and specific process flow choice [3].

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*D. Operation Determination*

These are the methods or steps to be taken in realizing a process, and this can be carried out using the results obtained from the product analysis and process selection phase. These include; determination and statement of the operations required to accomplish each process, determination and numbering of the sequence of operation, chronological specification of the raw material, machine name [10].

*E. Dual Axes Solar Power Generating System*

Dual Axes Solar Power Generating System (DASPGS) possess two degrees of freedom that act as rotation axes which are usually orthogonal to one another [11]. The principal axis is the one that is grounded. The secondary axis is the only one that refers to the primary axis. Dual trackers are commonly used in a variety of ways. Their classification is determined by the orientation of their primary axes to the ground [12]. DASPGS change both altitude (vertical) and azimuthal (horizontal) degrees of solar panels. They rotate and tilt to track the sun in both east to west and north to south directions to maximize the power output [13]. Research conducted by [14], stated that DASPGS outperform Fixed Axis Solar Power Generating System (FASPGS) because the earth has two kinds of motion: daily motion and annual motion. [15], explained further that, DASPGS combine the two motions (North to South and East to West) to track sunlight optimally. They adapt to the daily trajectory of the sun with seasonal tilting. The power output of the panels is maximized by using DASPGS because it can keep the panel perpendicular to the sun anywhere around the world and for a longer duration than FASPGS. Therefore, using DASPGS would boost solar panel efficiency.

## II. MATERIALS AND METHODS

*A. Materials*

The material selection that was used for fabrication and production of the DASPGS include the following: mild steel rod, mild steel pipe, mild steel bar, mild steel plate, galvanized steel pipe, chrome steel, aluminum pipe, carbon steel, and teflon. During the design process of the DASPGS components, three main steps were involved which include; product analysis process selection, and operation determination.

*B. Product Design and Analysis*

The following steps were followed in product analysis for the study of DASPGS which include: a detailed drawing of the DASPGS, an assembly drawing of the product, identification of all sub-assemblies and parts not attached to any particular assemblies, list of sub-assemblies and independent parts, list of parts on each of sub-assembly, list of material types for each identified type, drawing of the product structure tree chart, conducting a modify or buy analysis, and preparation of a Bill of Material (BOM) for product and assemblies.

*C. Process Selection*

The steps adopted in the process selection of DASPGS were highlighted in the following

- All features to be processed on each part were itemized,
- The surfaces to be created for each feature were also itemized
- For each surface itemized, all possible processes that could be used to create it were stated.
- Estimation of cost of processing, buying special jigs and fixtures for each stated process was made.

*D. Operation Determination*

The procedural steps that were adopted in the operation determination of the DASPGS are itemized and these include the following. Determination and statement of the operation required to accomplish each process selected. Determination numbering of the sequence of operations, Chronological specification of the raw materials, machine name, machine setup time, any special tools, jigs and fixtures, machine rate, etc. Superimposition of the above information on production identification number and product drawing number to obtain the process route sheet.

## III. RESULTS AND DISCUSSION

*A. Product Analysis*

The result of the product analysis of DASPGS was obtained mainly from the engineering drawings of parts and products. The major output of this product analysis is the product specifications of the DASPGS. Fig 1 and Fig 2 show the various drawings of DASPGS used in achieving the required result. Table 1 shows the list of identified components and types of material used in producing DASPGS. Table 2 shows the list of material specification numbers for easy identification of material in the production system. Table 3 is the alpha-numerical coding list that shows the product, unit, sub-assembly, and alpha-code columns of the components. Table 4 shows the list of parts and letter code. Table 5 shows the list of parts alpha-numerical code and materials specifications. Haven considered the procedural steps conducted on product analysis of the DASPGS, a product tree structure diagram was drawn and represented with different letter codes and material specification numbers for better specification and easy identification as represented in Figure 5.

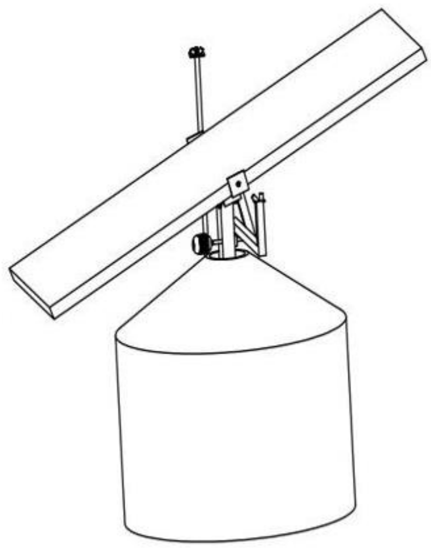

**Fig 1*:*** A Dual-Axes Solar Power Generating System

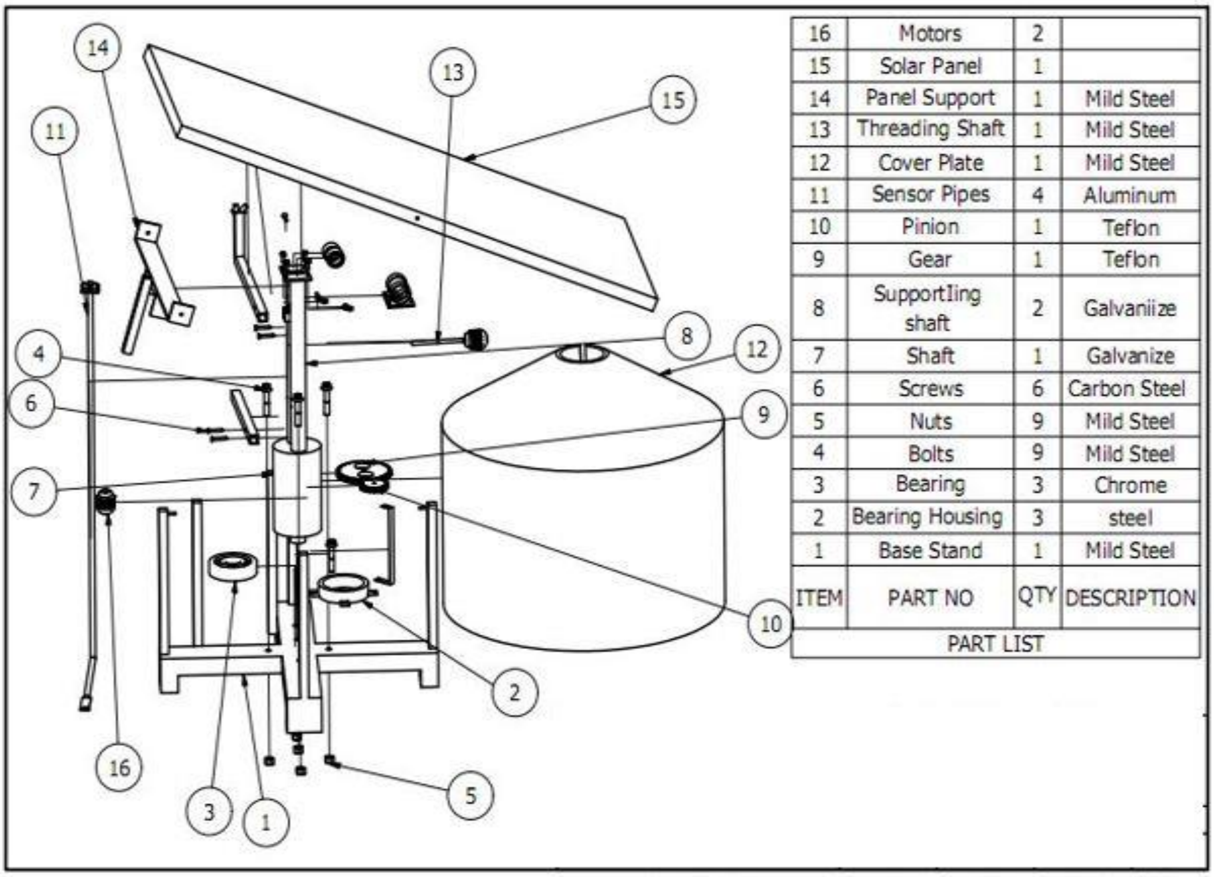


**Fig 2*:*** Part List of the Dual-Axes Solar Power Generating System

TABLE 1: LIST OF MECHANICAL COMPONENTS AND MATERIAL TYPE OF DASPG

| S/N | Component Name | Material Type |
|---|---|---|
| 1 | Base Stand | Mild Steel |
| 2 | Base Sensor Pipes | Aluminum |
| 3 | Base Bearing Housing | Mild Steel |
| 4 | Base Bearing | Chrome Steel |
| 5 | Base Bolts | Mild Steel |
| 6 | Base Nuts | Mild Steel |
| 7 | Base Motor Support | Mild Steel |
| 8 | Sensor Dual axis Pipe | Aluminum |
| 9 | Sensor Coordinate Pipe | Aluminum |
| 10 | Sensor Tilting pipe | Aluminum |
| 11 | Upper Bearings Housing | Mild Steel |
| 12 | Upper Bearings | Chrome Steel |
| 13 | Upper Bolts | Mild Steel |
| 14 | Upper Nuts | Mild Steel |
| 15 | Shaft | Galvanized Mild Steel |
| 16 | Supporting Shaft | Galvanized Mild Steel |
| 17 | Gear | Teflon |
| 18 | Pinion | Teflon |
| 19 | Screws | Carbon Steel |
| 20 | Cover Plate | Mild Steel |
| 21 | Threading Shaft | Mild Steel |
| 22 | Panel Support | Mild Steel |

TABLE 2: LIST OF MECHANICAL COMPONENTS AND MATERIAL TYPE OF DASPGS

| S/N | Material Type | Alphanumeric Code |
|---|---|---|
| 1 | Mild Steel Rod | MSR 100 |
| 2 | Mild Steel Pipe | MSP 100 |
| 3 | Mild Steel Bar | MSB 100 |
| 4 | Mild Steel Plate | MSP 100 |
| 5 | Galvanized Steel Plate | GSP 150 |
| 6 | Chrome Steel | CS 200 |
| 7 | Carbon Steel Pipe | CBP 200 |
| 8 | Aluminum Pipe | AP 300 |
| 9 | Teflon | TF 400 |

**TABLE 3:** LIST OF PRODUCTS, SUB-ASSEMBLY AND ALPHA-CODE

| Unit | Code | Sub-assembly | Code | Alpha-Code |
|---|---|---|---|---|
| Base | B | Stand | S | BS |
| | | Sensor Pipes | P | BP |
| | | Bearing Housing | B | BH |
| | | Bearing | B | BB |
| | | Bolts | O | BO |
| | | Nuts | N | BN |
| | | Motor Support | M | BM |
| Sensor | S | Dual axis Pipe | R | SR |
| | | Coordinate Pipe | C | SC |

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| | | | | |
|---|---|---|---|---|
| | | Tilting pipe | T | ST |
| Upper | U | Bearing Housing | H | UH |
| | | Bearings | B | UB |
| | | Bolts | O | UO |
| | | Nuts | N | UN |
| Shaft | S | | | S |
| Supporting Shaft | H | | | H |
| Gear | G | | | G |
| Pinion | P | | | P |
| Screw | W | | | W |
| Cover Plate | C | | | C |
| Threading Shaft | T | | | T |
| Panel Support | V | | | V |

TABLE 4: LIST OF COMPONENT PARTS AND LETTER CODE

| S/N | Component Name | Letter Code |
|---|---|---|
| 1 | Base Stand | BS01001 |
| 2 | Base Sensor Pipe | BP01001 |
| 3 | Base Bearing Housing | BH01001 |
| 4 | Base Bearing | BB01001 |
| 5 | Base Bolts | BO01001 |
| 6 | Base Nuts | BN01001 |
| 7 | Base Motor Support | BM01001 |
| 8 | Sensor Dual axis Pipe | SR01001 |
| 9 | Sensor Coordinate Pipe | SS01001 |
| 10 | Sensor Tilting Pipe | ST01001 |
| 11 | Upper Bearing Housing | UP01001 |
| 12 | Upper Bearings | UB01001 |
| 13 | Upper Bolts | UO01001 |
| 14 | Upper Nuts | UN01001 |
| 15 | Shaft | S01001 |
| 16 | Supporting Shaft | H01001 |
| 17 | Gear | G01001 |
| 18 | Pinion | P01001 |
| 19 | Screws | W01001 |
| 20 | Cover Plate | C01001 |
| 21 | Threading Shaft | T01001 |
| 22 | Panel Support | V01001 |

*B. Process Selection*

The results of the selection process for the manufacturing of a DASPGS are as follow drilling, lathe turning, facing, chiseling, sawing, punching, bending, rolling, and cutting. For each of the following processes selected, urgent attention was given to having the ability to produce parts to specifications. The process selected were those which simplified the operations while they also produce good surface finished. Table 6 represent process identification and selection. The completion was based on insight, experience, and expert opinion.

*C. Operation Determination*

The result of operation determination was derived and obtained using product analysis and process selection phases. The result of the tree structure diagram of DASPGS is represented in Figure 4. Also, Table 7 depicts the bill of material for DASPGS with parts letter code, required quantity, material specification number, and selected option between buying and modifying parts. Finally, Table 8 shows a long list of processes identified in the manufacture of DASPGS and the selected best process for each operation.

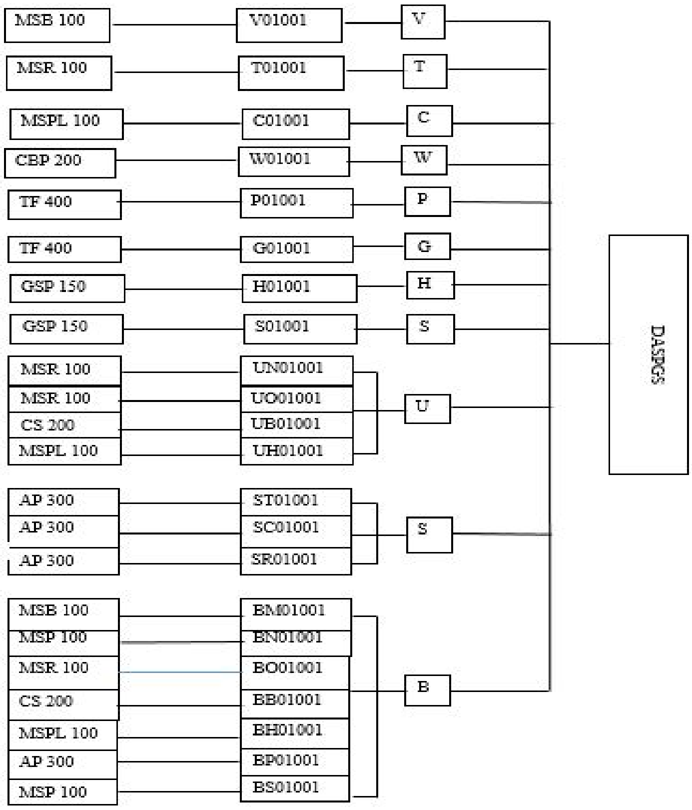


**Fig 3:** Three Structure Diagram of DASPGS

TABLE 6: LIST OF PARTS TO MODIFY AND PARTS TO BUY

| Parts to modify | | Parts to buy | |
|---|---|---|---|
| ***Part*** | ***Code*** | ***Part*** | ***Code*** |
| Base Stand | BS01001 | Base Bearing | BB01001 |
| Base Sensor Pipe | BP01001 | Base Bolts | BO01001 |
| Base Bearing Housing | BH01001 | Base Nuts | BN01001 |
| Base Motor Support | BM01001 | Upper Bearings | UB01001 |
| Sensor Dual axis Pipe | SR01001 | Upper Bolts | UO01001 |
| Sensor Coordinate Pipe | SS01001 | Upper Nuts | UN01001 |
| Sensor Tilting Pipe | ST01001 | Gear | G01001 |

| | | | |
|---|---|---|---|
| Upper Bearing Housing | UH01001 | Pinion | P01001 |
| Shaft | S01001 | Screws | W01001 |
| Supporting Shaft | H01001 | | |
| Cover Plate | C01001 | | |
| Threading Shaft | T01001 | | |
| Panel Support | U01001 | | |

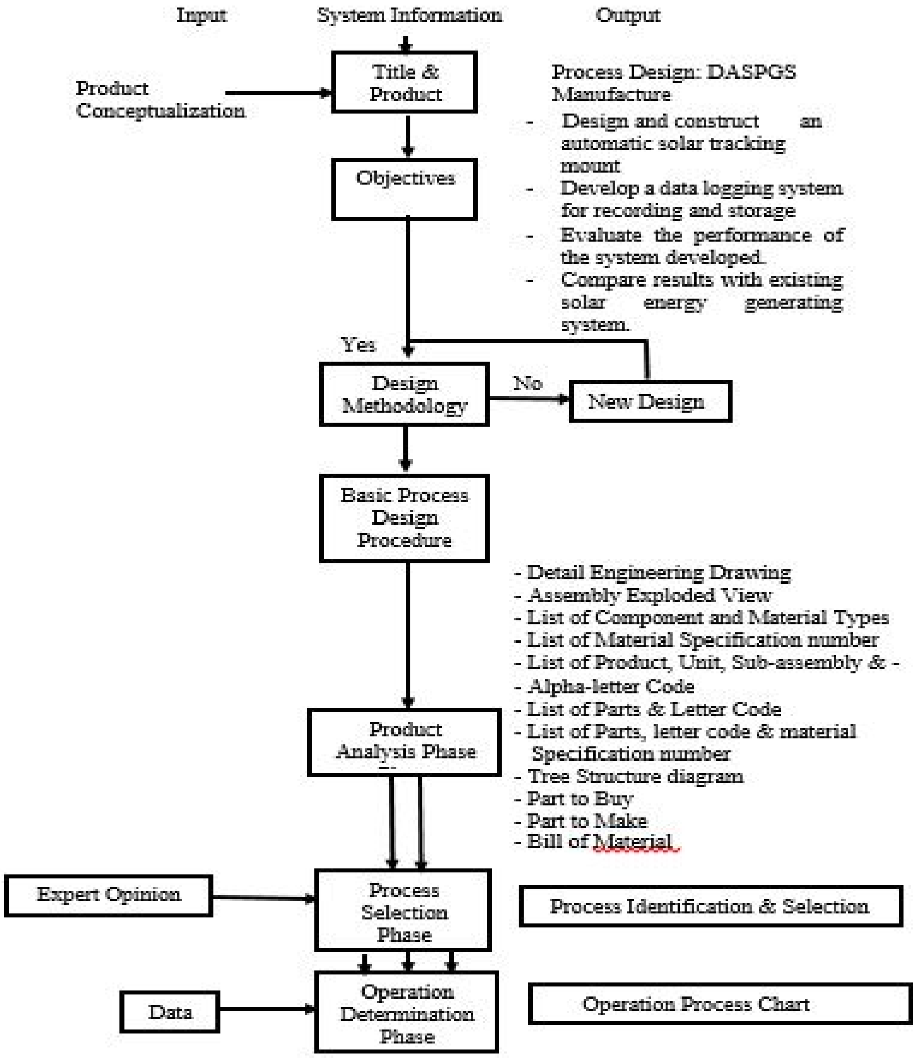


Fig 4: Model Procedure showing Process Design of DASPGS Manufacture

TABLE 7: BILL OF MATERIAL TO DASPGS

| S/N | Component Part (Part Code) | Quantity | Material Specification No. | Make (M) or Buy (B) |
|---|---|---|---|---|
| 1. | BS01001 | 1 | MSP 100 | M |
| 2. | BP01001 | 4 | AP 300 | M |
| 3. | BH01001 | 1 | MSPL 100 | M |
| 4. | BB01001 | 1 | CS 200 | B |
| 5. | BO01001 | 6 | MSR 100 | B |
| 6. | BN01001 | 6 | MSR 100 | B |
| 7. | BM01001 | 1 | MSB 100 | M |
| 8. | SR02002 | 2 | AP 300 | M |
| 9. | SS01001 | 1 | AP 300 | M |
| 10. | ST01001 | 1 | AP 300 | M |
| 11. | UH01001 | 2 | MSPL 100 | M |
| 12. | UB01001 | 2 | CS 200 | B |
| 13. | UO01001 | 4 | MSR 100 | B |

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|---|---|---|---|---|
| 14. | UN01001 | 4 | MSR 100 | B |
| 15. | S01001 | 1 | GSP 150 | M |
| 16. | H01001 | 2 | GSP 150 | M |
| 17. | G01001 | 1 | TF 400 | B |
| 18. | P01001 | 1 | TF 400 | B |
| 19. | W01001 | 6 | CSP 200 | B |
| 20. | C01001 | 1 | MSPL 100 | M |
| 21. | T01001 | 1 | MSR 100 | M |
| 22. | U01001 | 1 | MSR 100 | M |

TABLE 8: PROCESS IDENTIFICATION AND SELECTION

| S/N | Part Code | Measure and Surface to be Processed | Possible Process of Manufacture | Selected Process | Reasons |
|---|---|---|---|---|---|
| 1 | BS01001 | Flat Surface | Electric Arc Cutting, Sawing | Arc Sawing | Most appropriate since the plate is thick |
| 2 | BP01001 | Flat Surface | Sawing, Cutting | Sawing | Most appropriate |
| 3 | BH01001 | Flat Surface | Electric Arc Cutting, Sawing | Electric arc sawing | Easier and faster |
| 4 | BM01001 | Flat Surface | Sawing | Sawing | Most appropriate |
| 5 | SR01001 | Flat Surface | Sawing | Sawing | Appropriate, easier and economical |
| 6 | SS01001 | Flat Surface<br>Circular Holes | Sawing, Drilling, Sawing | Sawing, Drilling | Most appropriate<br>Easy and Economical |
| 7 | ST01001 | Flat Surface | Sawing | Sawing | Most appropriate |
| 8 | UH01001 | Circular Hole | Facing | Facing | Easy and Economical |
| 9 | S01001 | Circular Hole | Lathe Turning, Facing | Lathe | Easy and Economical |
| 10 | H01001 | Flat Surface<br>Circular Hole | Cutting, Sawing | Sawing | Simple and Easy |
| 11 | C01001 | Flat Surface | Rolling, Bending | Rolling | Produce a well round part |
| 12 | T01001 | Circular Flat Surface | Lathe Cutting, Cutting | Lathe Turning | Most appropriate |
| 13. | U01001 | Flat Surface | Cutting, Sawing | Sawing | Produce good finish surface |

## IV. CONCLUSION

This study has revealed the activities involved in each process design phase of DASPGS taken into consideration the fundamental situations in Nigeria. The review procedure of process design was then applied to the design of the DASPGS manufacturing process model. The tools used in process design and all the available procedures were utilized to achieve the stated objectives. The method has proven that using alpha-numeric codes for naming the component has made the components easy for recognition. The study has revealed the process design techniques that should be adopted in advancing and enhancing large-scale manufacturing of DASPGS.

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