GUIDANCE FOR ELECTROMECHANICAL DESIGNS OF NEW PUMPING STATIONS IN NATIONAL WATER SUPPLY AND DRAINAGE BOARD

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Degree of Master of Science in Electrical Installations

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science

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DECLARATION OF THE CANDIDATE & SUPERVISORS

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(Prof. J P Karunadasa)

ABSTRACT

National Water Supply and Drainage Board is the largest individual customer of Ceylon Electricity Board. It has been observed that the cost of electricity and the capital cost of investment can be reduced appreciably by adapting better electromechanical design methodologies for new pumping stations. Current practice is that foreign contractors do the design and construction on secured funds with their own equipment and procedures without much of a concern of the operational cost in the long terms. This project is to identify drawbacks in the existing pumping stations and drafting design guidelines for the new pumping stations to achieve lower capital cost and operational cost. Some of the key areas considered in this thesis are given below.

Collect data such as power rating, pump type, pump operating point and the number of motors available to check whether they operate at the best efficient point and to compare whether the design requirements are fulfilled.

Main objective of the research is to develop a software guided systematic approach to electromechanical designs of new pumping stations in the NWSDB taking cost, performance, service, and maintenance factors in to consideration.

The total flow rate, static head of pumping system, number of duty pumps and standby pumps are the basic input to this software. Details of piping and accessories are to be provided additionally to calculate the total head and NPSH availability. Web base software provided by the pump manufacturers are used to select most efficient pumps for the particular application. Power transformers, standby generators, power cables and circuit breakers are selected with the use of this software. Additionally, operational cost calculation is also carried out in order to rank and select the optimum combination of pumps for cost optimization.

The web base software has been developed to analyze the existing pumping systems and to design new pumping stations while maintaining lower capital cost and operational cost.

Key words:
Pumping stations, Cost optimization, Design guidelines, NWSDB

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H D S Priyathilaka

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LIST OF ABBREVIATIONS

Abbreviation	Description
CB	Circuit Breaker
CEB	Ceylon Electricity Board
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
kWh	kilo Watt hour
LKR	Lanka Rupees
LV	Low Voltage
MV	Medium Voltage
NPSH	Net Positive Suction Head
N RW	None Revenue Water
NWS&DB	National Water Supply and Drainage Board
OC	Over Current
O&M	Operation & maintenance
SCADA	Supervisory Control and Data Acquisition
VFD	Variable Frequency Drive

LIST OF APPENDICES

Chapter 1

INTRODUCTION

1.1 Background

National Water Supply and Drainage Board (NWS&DB) is the national institution for provision of potable water and it has so far been able to provide 43.4% of population with pipe borne water. There are other forms of water supply through rural water schemes run by local governments as well as consumer societies and hand pumps etc that account for additional 25% of population. As such the total safe drinking water supply coverage in the country is closer to 65% of population [1]. These statistics clearly show that we have to put a tremendous effort to fulfill 100% coverage of safe drinking water with the continuously increasing population in Sri Lanka.

The findings in this project would be useful for identifying drawbacks of the existing pumping stations and drafting software base guidance for the new pumping stations to achieve lower capital cost and operational cost.

1.2 Problems of the existing Pumping Stations

The followings problems have been observed in the existing pumping stations.

1) Specific energy, which is the number of kWh units needed to pump one cubic meter of water, is high. There is no specific design methodology to reduce specific energy consumption.

2) Optimum combination, the type, the speed requirement, the rating and the starting method of the pump motors have not been properly selected. This leads to extra cost for oversized transformers, generators, cables and other switchgear equipment in addition to the increase in energy cost.

3) Most of the pumping stations do not meet the design requirements.

4) In most cases, electromechanical Engineers in National Water Supply and Drainage Board have not been consulted in the preliminary design stages to negotiate electromechanical designs.

1.3 Motivation

As a developing country, we have to spend a considerable amount of capital especially for design works of the pumping stations of NWS&DB. Therefore, the only alternative is to develop some guidelines for mechanical and electrical design works related with pumping stations. A good quality design is an integral part of sustainable development and it puts water, drainage, energy, community, economic, infrastructure and other such resources to the best possible use over the long term as well as the short term.

1.4 Objective of the Study

The objectives of this project are listed below.

1) To investigate and identify the drawbacks of existing pumping stations.
2) To implement software base design guidance for the new electromechanical designs and thereby contribute to national economy by improving reliability, redundancy and reduced electricity cost.
3) Use of software base guidance to enhance the design and selection of optimum combinations of pumps.

1.5 Thesis Outline

After this introductory chapter, chapter 2 provides algorithms for Electro-mechanical Design Procedure. These algorithms include implementation of water supply projects, selecting pumps, transformers, generators, cables, breakers and operating cost calculations. Chapter 3 provides information on software development and selection using implemented calculating interfaces. Chapter 4 describes how to analyze the existing pumping stations using the calculating interfaces. Validation of the interfaces is demonstrated in chapter 5. Finally, Chapter 6 provides the conclusion and recommendations.

Chapter 2

ALGORITHM FOR ELECTRO-MECHANICAL DESIGN PROCEDURE

2.1Implementation of water supply projects

The capacity of a domestic water supply scheme is determined based on an average daily demand, which is obtained by estimating the sum of respective uses, i.e., domestic use, public facility consumption, commercial/business consumption and industrial uses. In case there is no sufficient data to identify the daily demand in terms of respective uses, it is customary to estimate the average daily demand from the daily per capita consumption multiplied by design population size. In municipalities values of 200 to 500ltr/capita/day are adopted, larger values being applied to developed cities. Appropriate estimation on population increase is essential in planning a public water supply scheme, for which 10 to 20 years' prospects are often applied.

A typical procedure to develop a municipal water supply project is shown in Fig. 2-1. In order to meet the expected increases in future demands facility expansions are often formulated to take a phased build-up plan against years as illustrated in Fig. 2-2.

The design average daily supply capacity is determined by taking into account unavoidable leakage during transportation and necessary water volume for purification processes and this is known as None Revenue Water. The average daily supply is derived from the average daily demand divided by "effectiveness" which depends on degree of effective transportation being in the range of 0.9 depending on regional conditions including losses in leakage.

The maximum daily supply is determined taking into account variations in demand according to days of the week as well as seasonal changes in demand. The ratio of the average daily supply to the maximum daily supply is called "load ratio" being in the rage of 0.7 to 0.8 depending on character of the city, higher values being applied to larger cities. The maximum daily supply is used for the basis of the treatment capacity. Raw water intake capacity is also determined taking 10% margin over the maximum daily supply. [2]

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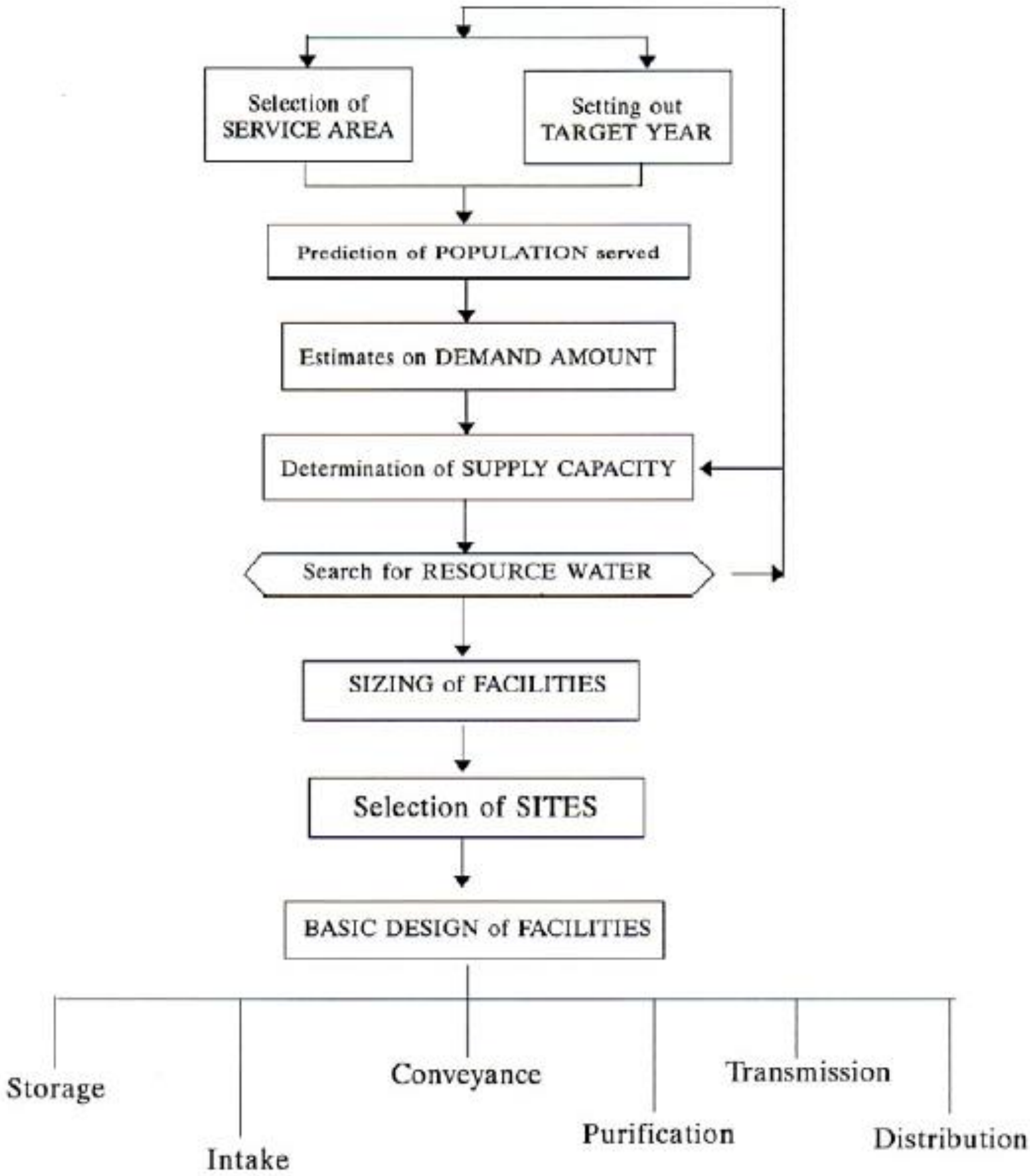

Figure 2.1: Procedure for Implementation of Water Supply Projects.

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

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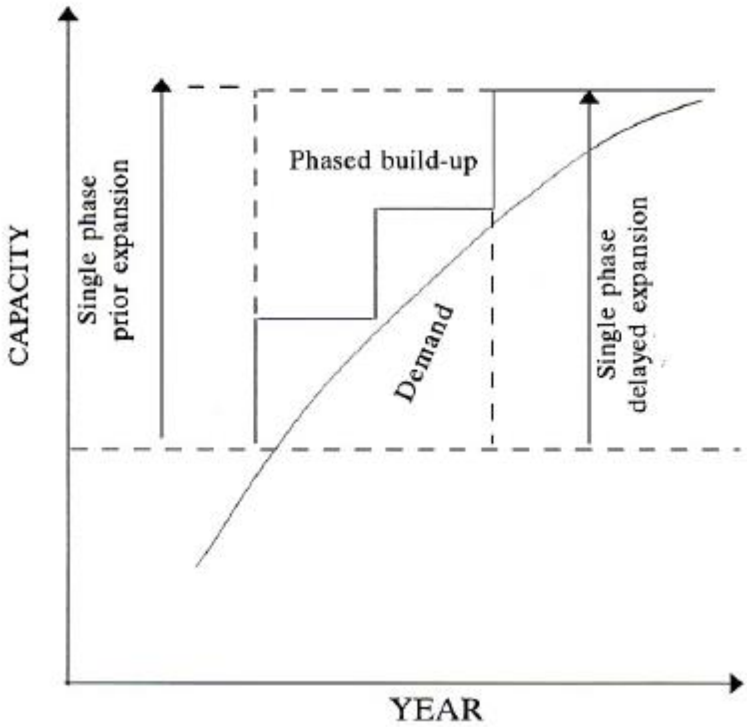


Figure 2.2: Facility Expansion Plan (Phased build-up plan against years to cope with expected increases in future demands)
Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

2.2 Selecting M&E equipment

Under the M&E equipment selection, the following major components are considered for the selection process.

1. Power Transformer.
2. Standby Generator.
3. Water Pumps.
4. Power Cables.

General algorithm for selecting M&E equipment is illustrated in Fig. 2.3. Pump combinations and the total evaluated cost are taken into consideration.

GENERAL ALGORITHM FOR SELECTING M&E EQUIPMENT

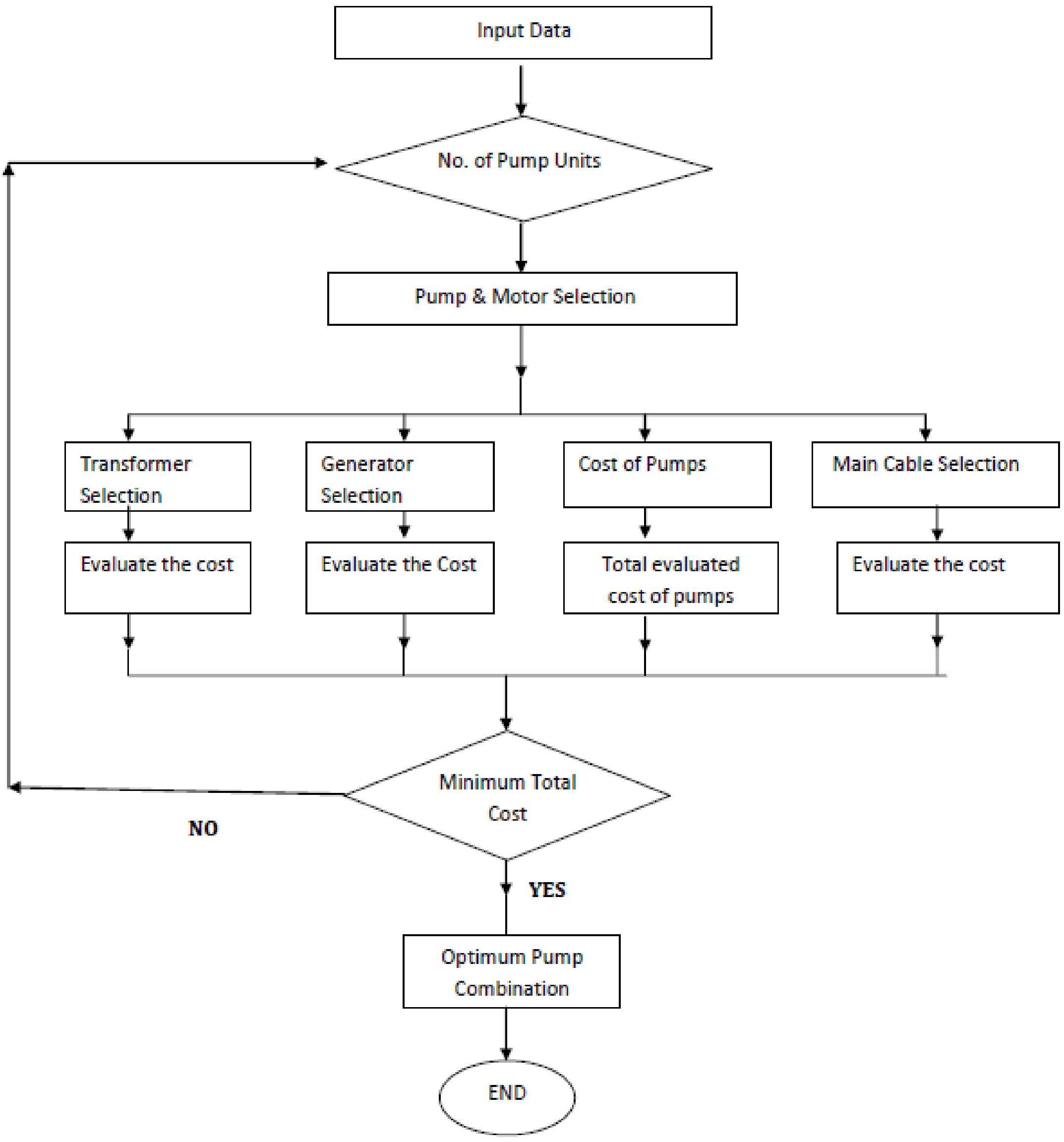


Figure 2.3: General algorithm for selecting M&E equipment.

2.3 Selecting the Pumping Unit

The basic requirements of a pumping unit for various water-works are determined by following the appropriate procedure utilizing relevant data as required. For standardized smaller units, the requirements can be easily identified referring to available manufacturers' catalogue data. Selecting the pumping unit is carried out by the steps 1 to 10.

(1) The unit capacity is determined from the required total capacity and the number of units selected. Combination of different unit capacities may be advantageous for meeting variable demands and the methodology is included in this thesis.

(2) The pump suction bore is selected in accordance with the unit capacity referring to Table 2.1.

Table 2.1: Capacities versus Pump Bores

BORE (mm)	CAPACITY (m^3/min)	BORE (mm)	CAPACITY (m^3/min)	BORE (mm)	CAPACITY (m^3/min)
65	0.35~0.45	350	12 ~ 18	1000	115 ~ 150
80	0.45~0.70	400	18 ~ 23	1200	150 ~ 200
100	0.70~1.20	450	23 ~ 28	1350	200 ~ 225
125	1.20~1.80	500	28 ~ 36	1500	255 ~ 325
150	1.80~3.00	600	36 ~ 50	1650	325 ~ 400
200	3.00~5.00	700	50 ~ 70	1800	400 ~ 480
250	5 ~ 8	800	70 ~ 90	2000	480 ~ 600
300	8 ~ 12	900	90 ~115	2200	600 ~ 740

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009

(3) The actual head is obtained from the design water levels at suction and discharge sides taking into account the hydraulic gradients in suction approach and discharge channels.

(4) Value of the required total head is assumed based on the design-actual-head and friction losses in the contemplated piping arrangement.

(5) The pump type is selected in accordance with the assumed total head, referring to Table 2.2 and relevant data in the Appendix I. The installation position and shaft direction is also selected to suit installation conditions.

Table 2.2: Selection of Pump Types

Pump Type	Specific Speed	Total Head		Bore
		Horizontal	Vertical	
Centrifugal (Radial flow)	100 ~ 600	Single stage 10 ~ 150 m Multi-stage > 50 m	Single stage 10 ~ 200 m Multi-stage > 10 m	≧ 40 mm
Mixed flow	400 ~1,400	4 ~15 m	Single stage 4 ~ 60 m Multi-stage > 10 m	≧200 mm
Axial flow	1,300 ~ 2,000	< 6 m	< 8 m	≧300 mm

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

(6) The pump speed, N is provisionally determined from the selected specific speed referring to equation 3-1, and adjusted with the prime mover speed when direct coupling is applicable.

$$N = Ns \cdot \frac{H^{3/4}}{\sqrt{Q}} \qquad \text{......................... (3-1)}$$

Where

Ns : Specific Speed

H : Total Head (m)

Q : Capacity (m^3/min)

(7) The assumed pump speed is checked for suction performance by referring to equations 3-2 and 3-3. An appropriate margin is provided in the NPSH available over the expected operating range.

$H_{SV} = H_A + hs - h_l - h_v$ …………………….. (3-2)

Where H_{SV}: NPSH Available (m)

H_A: Absolute pressure head acting on suction liquid (m)

hs : Suction actual head (m) (for suction lift, it takes a negative value)

Refer table 2.3 for suction water surface exposed to atmosphere.

h_l : Frictional head loss in suction pipe (m)

h_v : Saturated vapor pressure head (m) Refer table 2.4

Table 2.3: Atmospheric pressure head versus altitude

Altitude (m)	**0**	**200**	**400**	**800**	**1000**	**1500**	**2000**	**3000**
Pressure (mH_2O)	**10.33**	**10.20**	**9.85**	**9.38**	**9.17**	**8.64**	**8.12**	**7.16**

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

Table 2.4: Saturated vapor pressure

Temp. (^oC)	**0**	**10**	**20**	**30**	**40**	**60**	**80**	**100**
Press. (mH_2O)	**0.06**	**0.13**	**0.24**	**0.43**	**0.75**	**2.03**	**4.83**	**10.33**

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

$h_{sv} = [(N \cdot \sqrt{Q})/S]^{4/3}$ …………………….. (3-3)

(8) The layout for pumping units, connecting pipes and valves is made for exact calculation of the friction losses.

(9) After determining the design total head, selection of the pump type and bore is finalized. Suction performance is reconfirmed with regard to installation position relative to the minimum suction water level.

(10) The required rated output of the prime mover is determined in accordance with equation 3-4 based on assumed pump efficiency and power transmission method.

$$L_d = \frac{L_w}{e_p \cdot e_t} \cdot (1 + a) \qquad \text{……………………. (3-4)}$$

Where

L_d: Prime mover output (kW)

L_w: Pump output (kW0 as given by equation (3-5)

$\mathbf{e_p}$: Pump efficiency.

$\boldsymbol{e_t}$: Transmission efficiency.

$\boldsymbol{a}$: Allowance factor, = 0.1 – 0.2 for motors.

= 0.15 – 0.25 for engines.

$$L_w = \rho g (Q/60) H / 1{,}000 \qquad \text{……………………. (3-5)}$$

where L_w: pump output (kW)

ρ : density of liquid (kg/m^3)

g : acceleration of gravity (m/s^2)

Q : capacity (m^3/min)

H : total head (m)

The design procedures outlined above are illustrated in figure 2.4 in which respective sections to be referred to be shown.

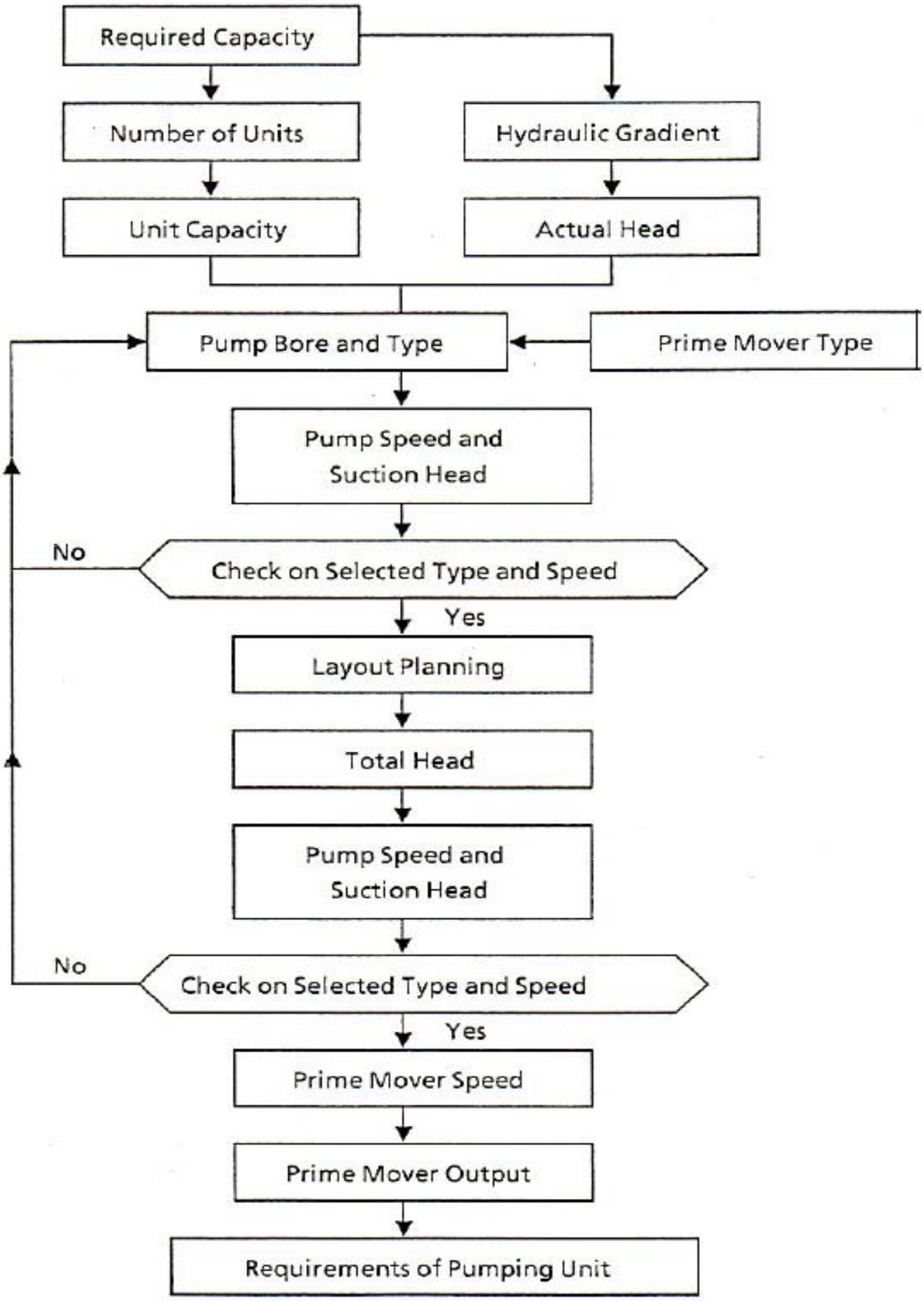


Figure 2.4: General algorithm for selecting the Pumping Unit.

Source: Planning and Design of Pumping Works, Ebara Corporation, 3rd ed., 2009.

2.4 Selecting Power Transformer

The equation 3-6 is used to determine the rating of the transformer

$$TR = (\Sigma P1 / (\eta \times \Phi) + \Sigma P2 + \sqrt{3} \times \Sigma P3) \times \alpha \times \beta \ldots\ldots (3\text{-}6)$$

Where

Pm	: Maximum motor in kW
β	: Demand factor
η	:General Efficiency
φ	: General power factor
α	: Surplus factor
$\Sigma P1$	: Three phase load capacity (kW)
$\Sigma P2$	: kVA Load Equipment
$\Sigma P3$	: Single phase load Equipment (kVA)
C	: Motor starter factor (Refer the table 2.5 for the data)
p	: Starting kVA for max. motor per kW

After calculating the size of the transformer, next highest standard rating of available capacity is selected. Available rated capacities in kVA are 5, 100, 160, 250, 400, 630, 800, 1000, 2000, 3000. Then the voltage regulation is checked by the following equation.

$$\text{Voltage Regulation (\%)} = \frac{\text{Transformer Starting Capacity x Transformer Z(\%)}}{\text{Transformer Capacity Selected}} \ldots\ldots..(3\text{-}7)$$

If the voltage regulation is less than 10%, the rating is acceptable. Otherwise repeat the calculation with the next highest rating available. Table 2.5 shows the Short Circuit Impedance of a Transformer

S/S Impedance	
Rated Power (kVA)	%
25 to 630	4.0
631 to 1250	5.0
1251 to 2500	6.0
2501 to 6300	7.0
6301 to 25 000	8.0

Table 2.5: Short Circuit Impedance of a Transformer

Source: 60076-5 © IEC:2000

Transformer starting capacity is calculated using the following equations.

The equation 3-8 is used to determine the base load capacity of the transformer in kVA (K1).

K1= Transformer Capacity - Max. Load capacity in kVA……………..(3-8)

The equation 3-9 is used to determine the starting load capacity of the transformer in kVA (K2).

K2 = Max Load Capacity(kW) x Starting factor………………..……..(3-9)

The equation 3-10 is used to determine the Active Power of the transformer in kW (P).

$P = K1\cos\Theta_1 + K2\cos\Theta_2$…………………………………..………..(3-10)

Where

$\cos\Theta_1$= general power factor

$\cos\Theta_2$= Starting power factor (assumed to be 0.4)

The equation 3-11 is used to determine the Reactive Power of the transformer in kVar (Q).

$Q= K1\sin\Theta_1 + K2\sin\Theta_2$ ……………..(3-11)

The equation 3-12 is used to determine the Total Starting Capacity of the transformer in kVA.

Total Starting Capacity (kVA) = √(P2 +Q2) ……………..(3-12)

Table 2.6 shows the Starting factor of motors

Starter Name	Starting factor,C
Direct on-line	1.00
Star-Delta	0.66
Star-Delta with resistor	0.33
VFD	0.17
Wound-rotor type	0.17
Reactor 50%	0.50
Reactor 65%	0.65
Reactor 80%	0.80
Auto-transformer 50%	0.25
Auto-transformer 65%	0.42
Auto-transformer 80%	0.64
Soft Starter	0.42

Table 2.6: Starting factor of motors

General algorithm for selecting the power Transformer is illustrated in Figure 2.5.

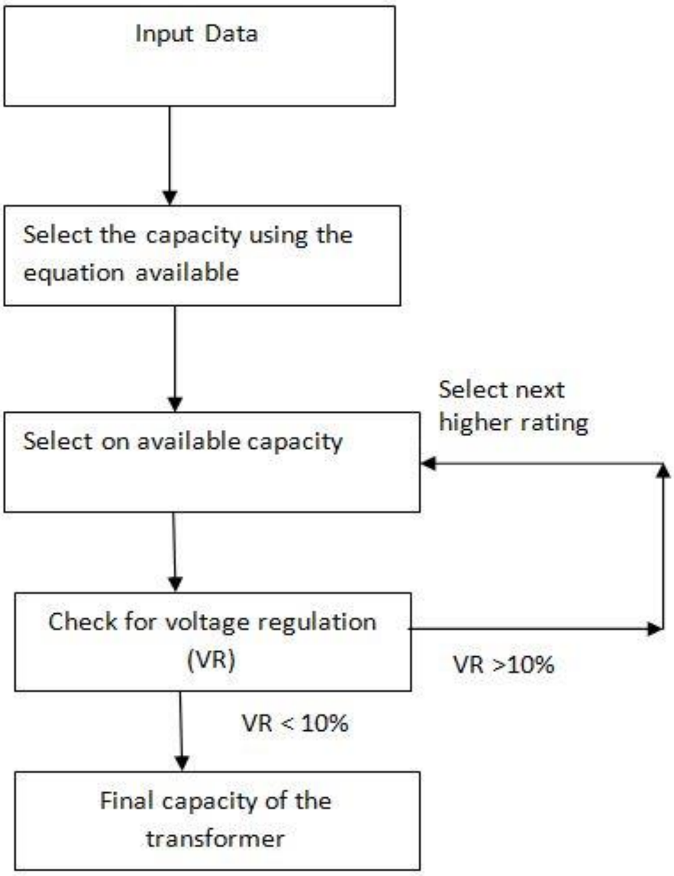


Figure 2.5: General Algorithm for selecting the Power Transformer.

2.5 Selecting Standby Generator

When sizing a generator, capacity is selected under the following conditions using the relevant equations.

(a) Capacity by considering the stabilized operation. – PG1

$$PG1 = \Sigma P0 \times \alpha \times Sf / (\eta_L \times \Phi_L) \quad \ldots\ldots(3\text{-}13)$$

(b) Capacity by considering allowable voltage drop. - PG2

$$PG2 = Pm \times \beta \times C \times Xd' \times (1-\Delta E) / \Delta E \quad \ldots\ldots(3\text{-}14)$$

(c) Capacity by considering starting the maximum motor lastly - PG3

$$PG3 = (fv1 / \gamma_G) \times [(\Sigma P0 - Pm) \times (\alpha /(\eta_L \times \varphi_L)) + Pm \times \beta \times C] \quad ..(3\text{-}15)$$

Where

Pm	: Maximum motor in kW
β	: Starting kVA for max. motor per kW
C	: Motor starter factor
fv1	: Derating factor of load starting
η_L	: General efficiency
φ_L	: General power factor
α	: Demand factor
Xd'	: Alternator factor
$\Sigma P0$	: Total load capacity covered by generator in kw
Sf	: Current increasing factor due to unbalanced load
ΔE	: Allowable voltage drop factor
γ_G	: Tolerant capacity for momentary overload of alternator

General algorithm for selecting the power Transformer is illustrated in Figure 2.6.

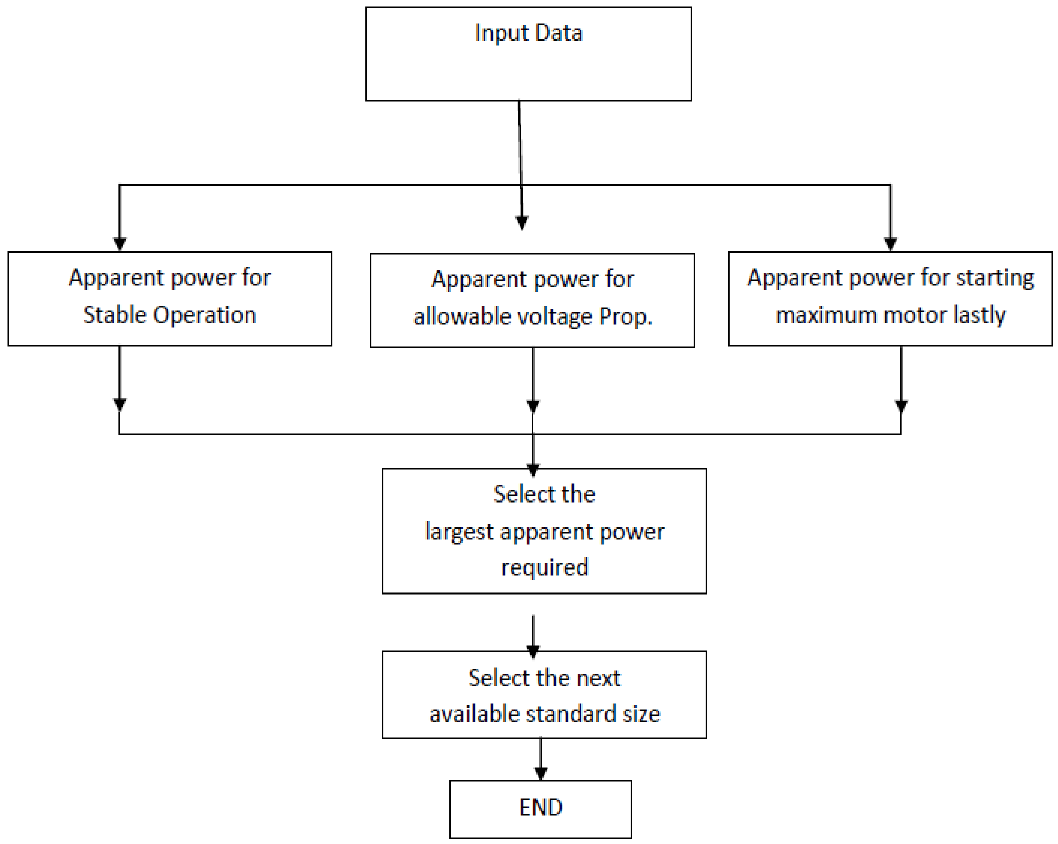


Figure 2.6: General algorithm for selecting Standby Generator.

2.6 Calculating total evaluated cost of pumping sets

General procedure for evaluating the pumping set by considering the operational cost is given below.

1. Data such as capacity of the pump, efficiencies, and annual operational hours are to be provided.
2. Then electrical energy used by a pump is calculated.
3. If the average cost of electricity per kWh is provided, cost of electrical energy for a pump is found.
4. After deciding the economic life of the pumping set and the discounting rate, present value of the cost of electrical energy per year for a pump is calculated. Then the cost of electrical energy per year for a pump is multiplied by the number of operational pumps to calculate the total present value of the cost of electrical energy per year.

5. Finally, capital cost of all the operational pumping sets is to be added to the total present value of the cost of electrical energy per year to calculate the total evaluated cost.

By using this procedure, we can evaluate the energy efficiency of pump motors in addition to the capital cost and reject the pump motors of having low efficiency.

2.7 Selecting Power Cables and Breakers

General algorithm for selecting power cables and breakers is illustrated in Figure 2.7.

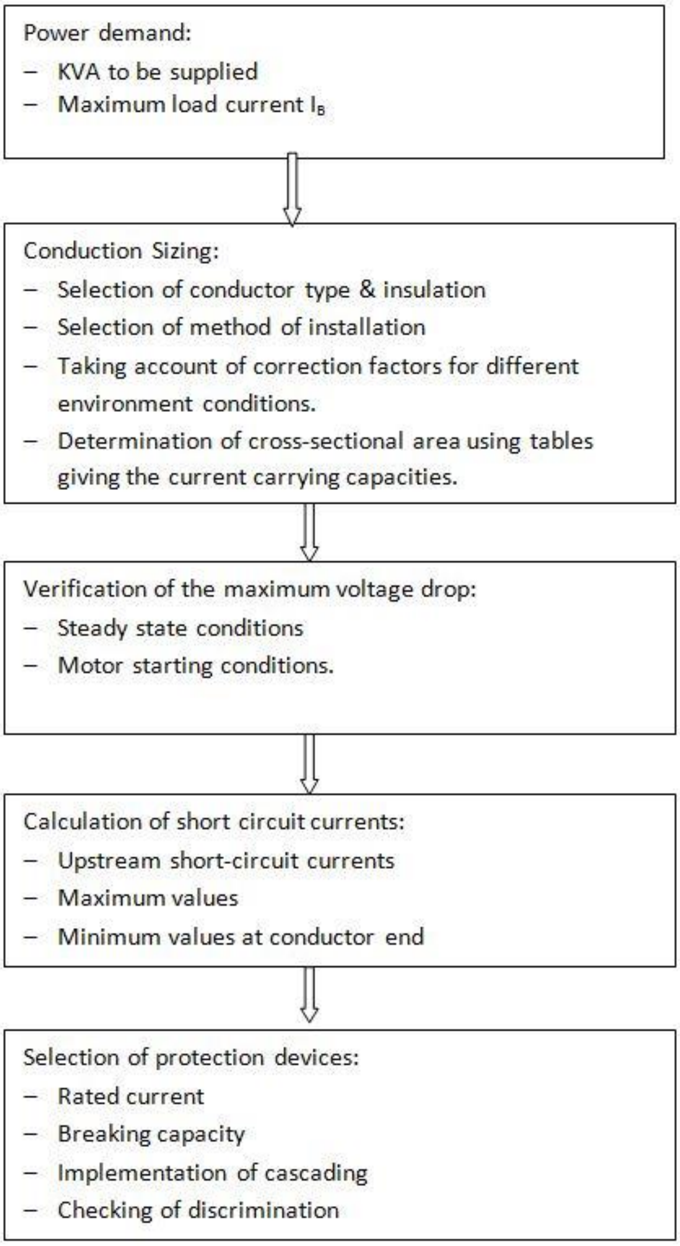


Figure 2.7: General algorithm for Power Cables and Breakers.

Source: Schneider Electric Industries SAS, ‘Electrical installation guide”, Schneider Electric, 2015.

2.8 The Algorithm for Selecting M&E Equipment in Pumping Station

Appendix 2 shows the complete algorithm for Selecting M&E Equipment in a Pumping Station. According to the algorithm given in Appendix 2, different pump combinations are analyzed together with other major M&E equipment. Capital cost and the operation cost of the pumping sets are considered for evaluation. This algorithm is used to design new pumping stations and to check the validation of existing pumping stations.

Chapter 3

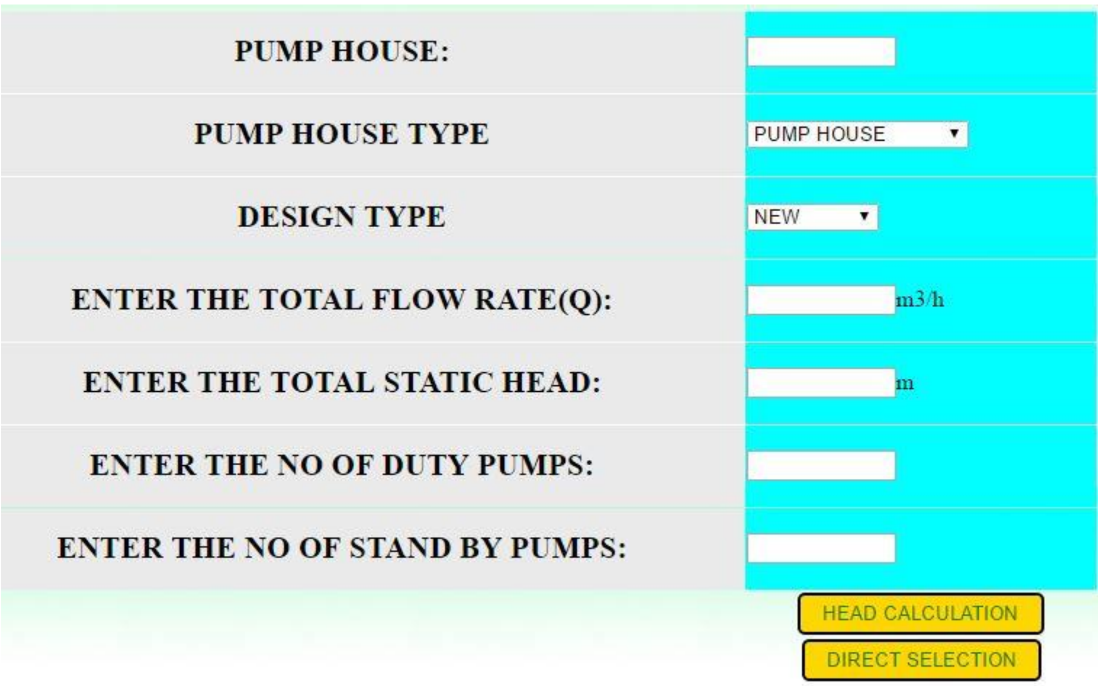
SOFTWARE DEVELOPMENT AND SELECTION USING CALCULATING INTERFACES

3.1 Software Development

When developing the software interfaces, WampServer was used as the windows web development environment. It was used to create web applications with PHP and MySQL database. Php MyAdmin was used to manage the database. PHP is widely-used open source general-purpose scripting language that is especially suited for web development and it can be embedded into HTML. HTML is the standard language which was used to create web pages and web applications

3.2 Selecting the Pumping Unit

When selecting the pumping unit, the following basic information are to be filled. When designing new pumping stations, total head and NPSH availability are to be calculated. In case of existing pumping stations, direct selection is carried out with the available information.



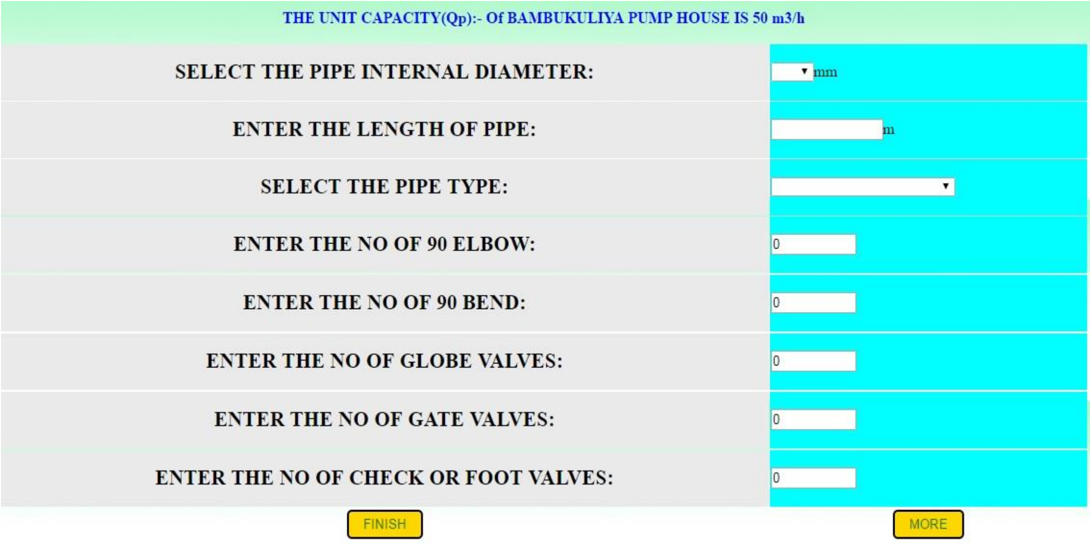


Figure 3.1: Selecting the pumping unit

The total head of the pumping system is the sum of static head and the frictional head. The figure 3.2 indicates the data are to be filled to calculate the total head and NPSH availability.

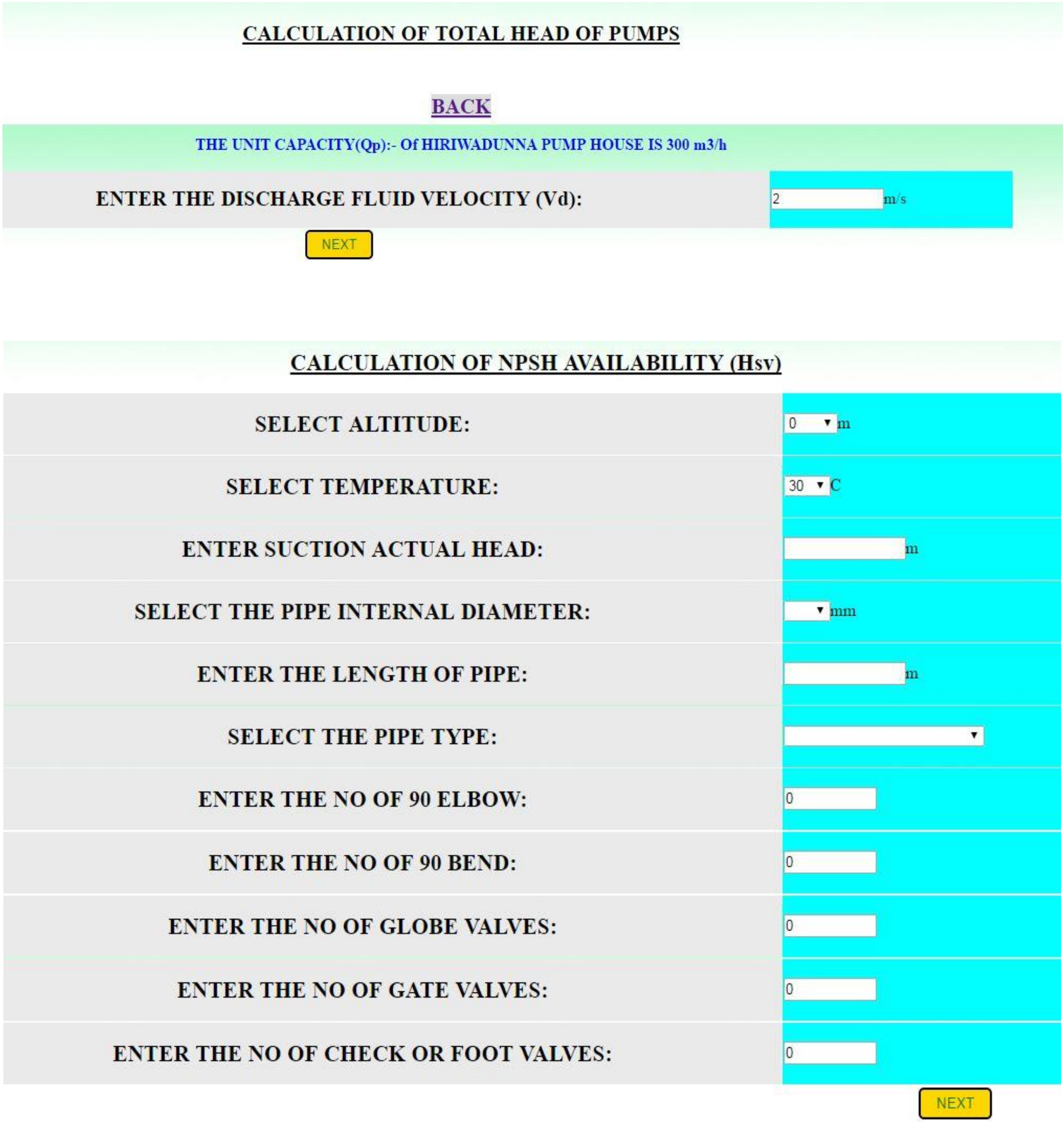


Figure 3.2: Calculating total head and the NPSH availability of pumping unit

After determining the NPSH availability, web base software is used to select the most suitable available pump. NPSH required should always be less than the NPSH availability of the selected pumping set.

Figure 3.3: Data for calculating total cost of pumping unit

After selecting the pump and motor, additional information such as power, efficiency, power factor, etc. are available to further calculations. Then the load list is to be prepared to determine the ratings of transformer, standby generator and power cables.

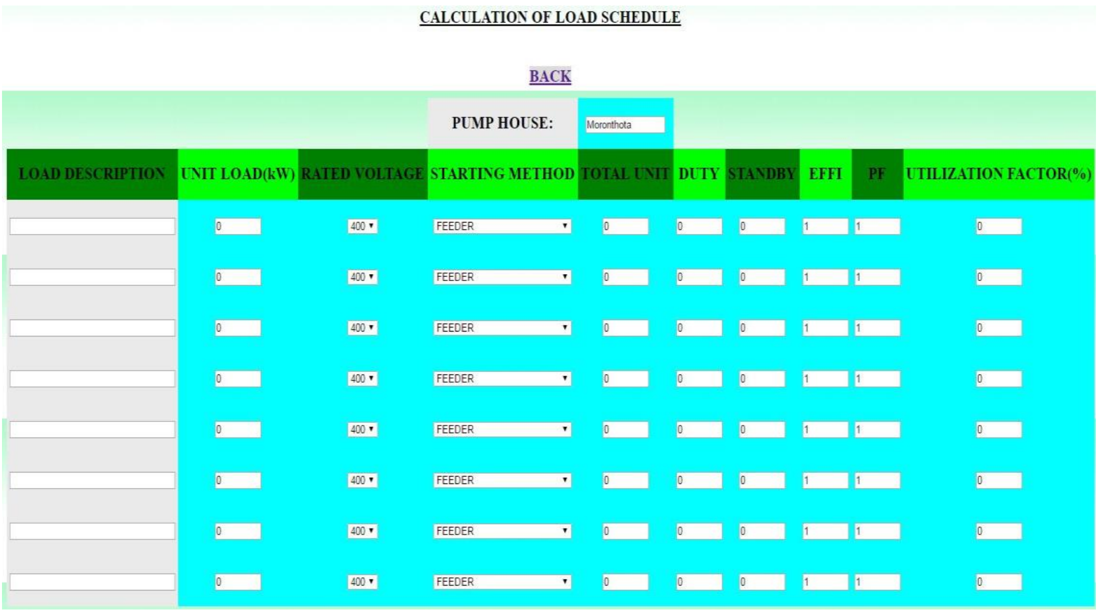
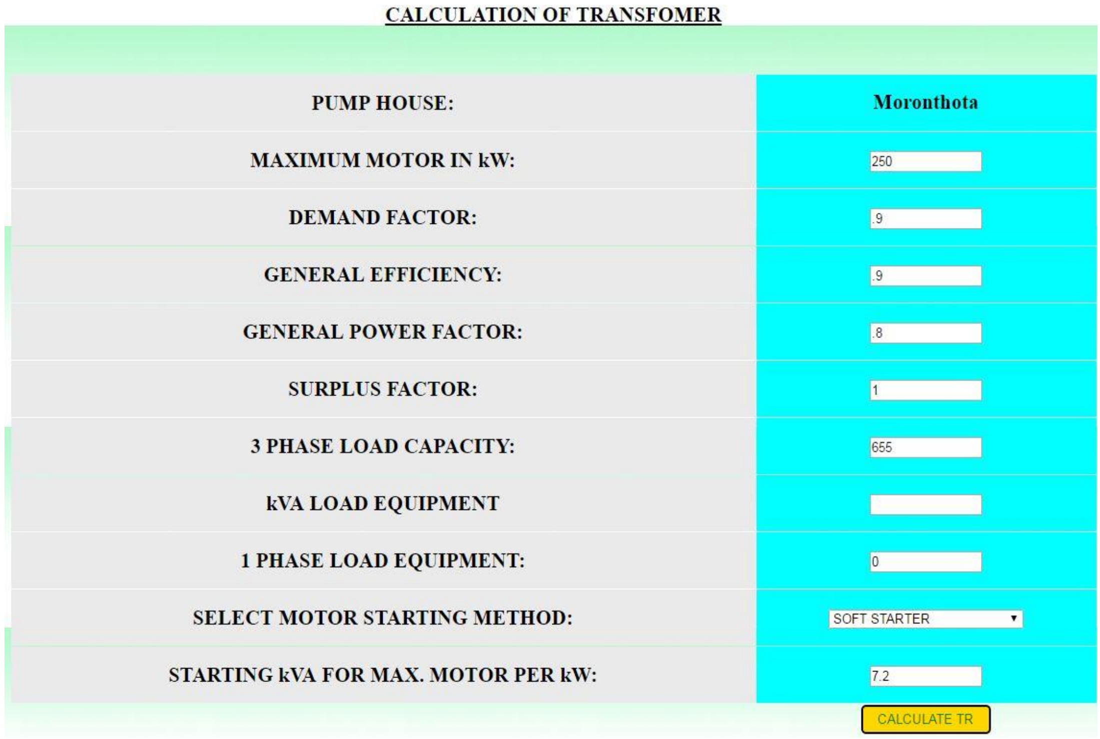


Figure 3.4: Load schedule

3.3 Selecting Transformer

The data from the load list is used to determine the rating of the transformer.



CALCULATION OF TRANSFOMER

PUMP HOUSE:	Moronthota
MAXIMUM MOTOR IN kW:	250
DEMAND FACTOR:	.9
GENERAL EFFICIENCY:	.9
GENERAL POWER FACTOR:	.8
SURPLUS FACTOR:	1
3 PHASE LOAD CAPACITY:	655
kVA LOAD EQUIPMENT	
1 PHASE LOAD EQUIPMENT:	0
SELECT MOTOR STARTING METHOD:	SOFT STARTER
STARTING kVA FOR MAX. MOTOR PER kW:	7.2
	CALCULATE TR

Figure 3.5: Data for selecting the transformer

After calculating the minimum rating of the transformer, the next highest available rating is to be selected. Then the selected rating is checked against a voltage regulation of 10%. If the voltage regulation is less than 10%, the selected capacity is acceptable. Otherwise the next higher rating of the transformer is to be checked until the condition of the voltage regulation requirement is met.

Figure 3-6 shows whether the transformer is acceptable or not. Then the cost of the transformer is also entered for determining the minimum total cost for different combinations.

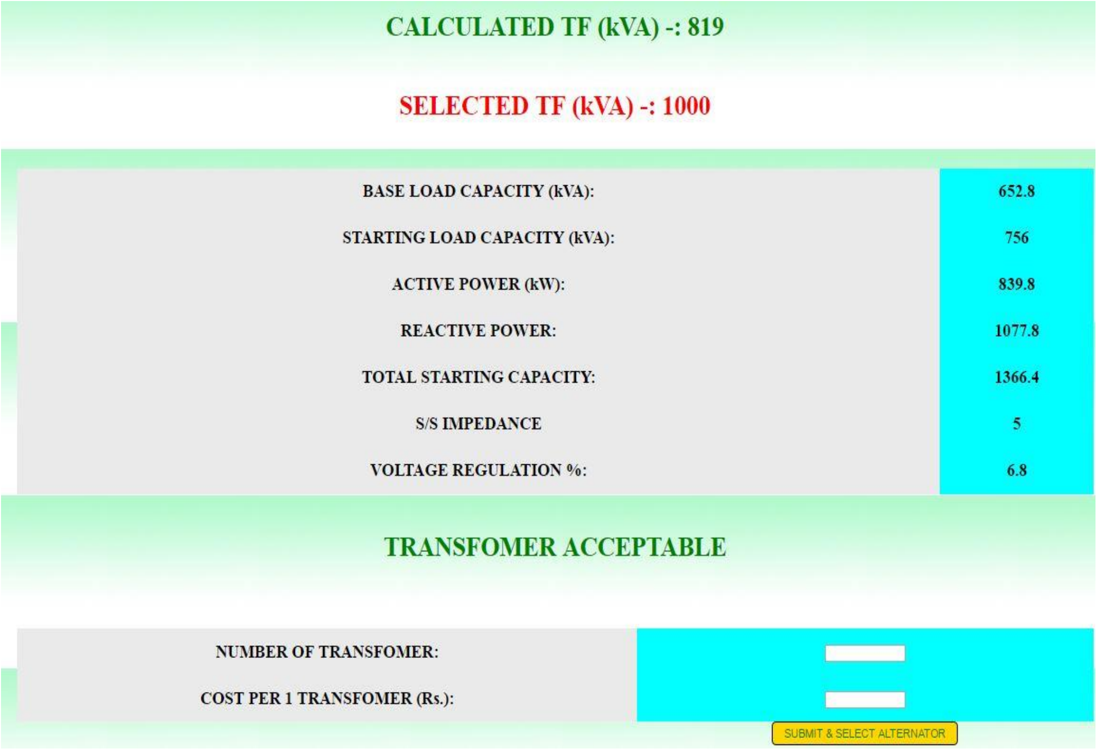


Figure 3.6: Final selection of the transformer

3.4 Selecting Standby Generator

The figure 3.7 shows the data to be entered to determine the size of the standby power generator.

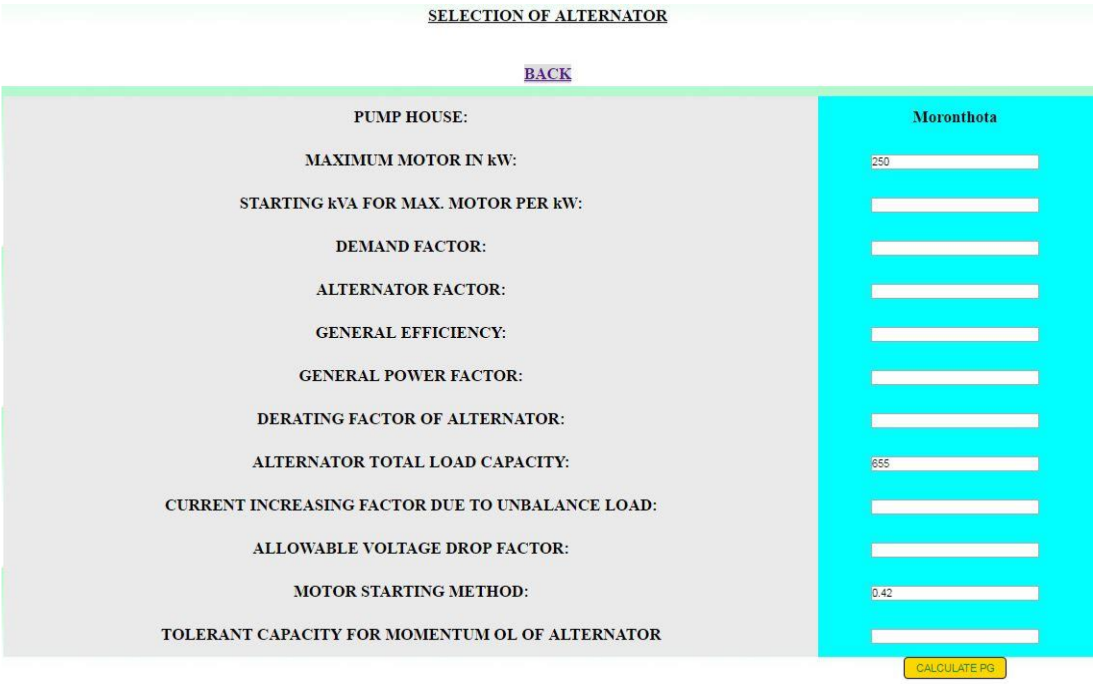


Figure 3.7: Data for selecting the Standby Generator

When sizing a generator, capacity is selected under the following conditions using the relevant equations.

(a) Capacity by considering the stabilized operation. – PG1

(b) Capacity by considering allowable voltage drop. - PG2

(c) Capacity by considering starting the maximum motor lastly - PG3

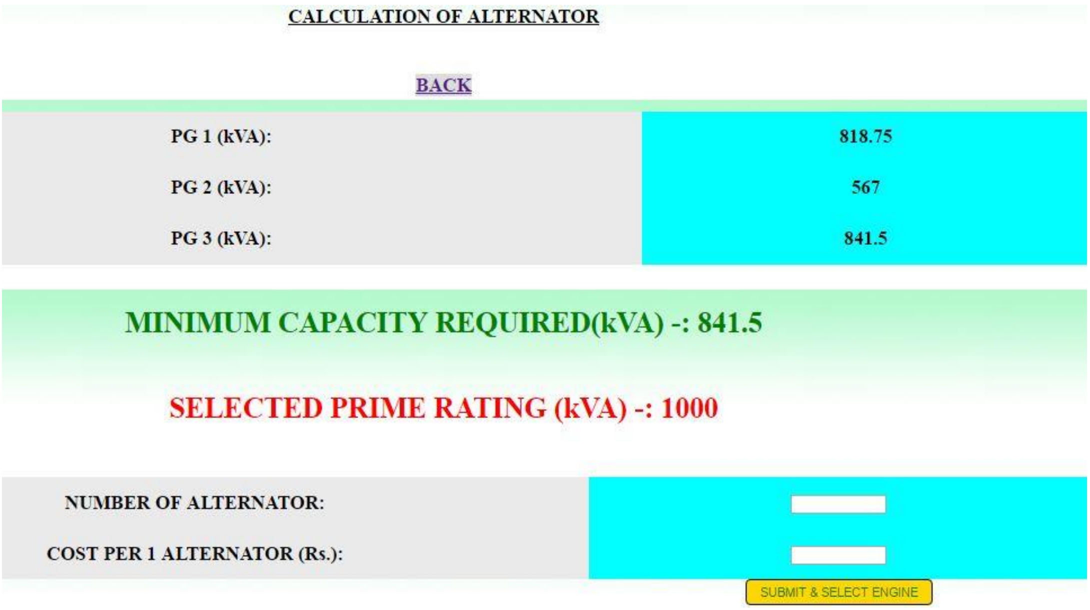


Figure 3.8: Final selection of the Standby Generator

3.5 Calculating total evaluated cost of a pumping set

Then the total evaluating cost of the pumping set is found by considering capital cost and operating cost of the pumping set. The life time of the pumping sets is assumed as 10 years and the discounting factor is assumed as 12% for all the calculations.

3.6 Selecting Power Cables and Breakers

The figures 3.9 to 3.12 indicate how to determine the rating of power cabling and circuit breakers for the same.

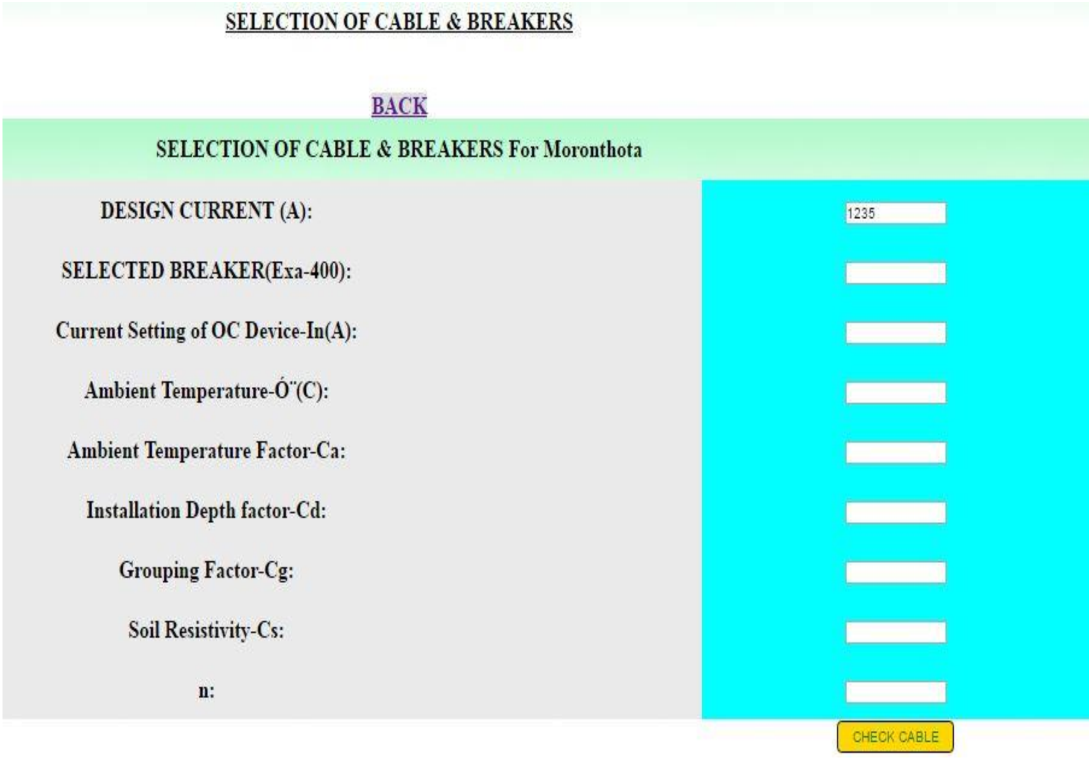


Figure 3.9: Data for selecting Power Cables

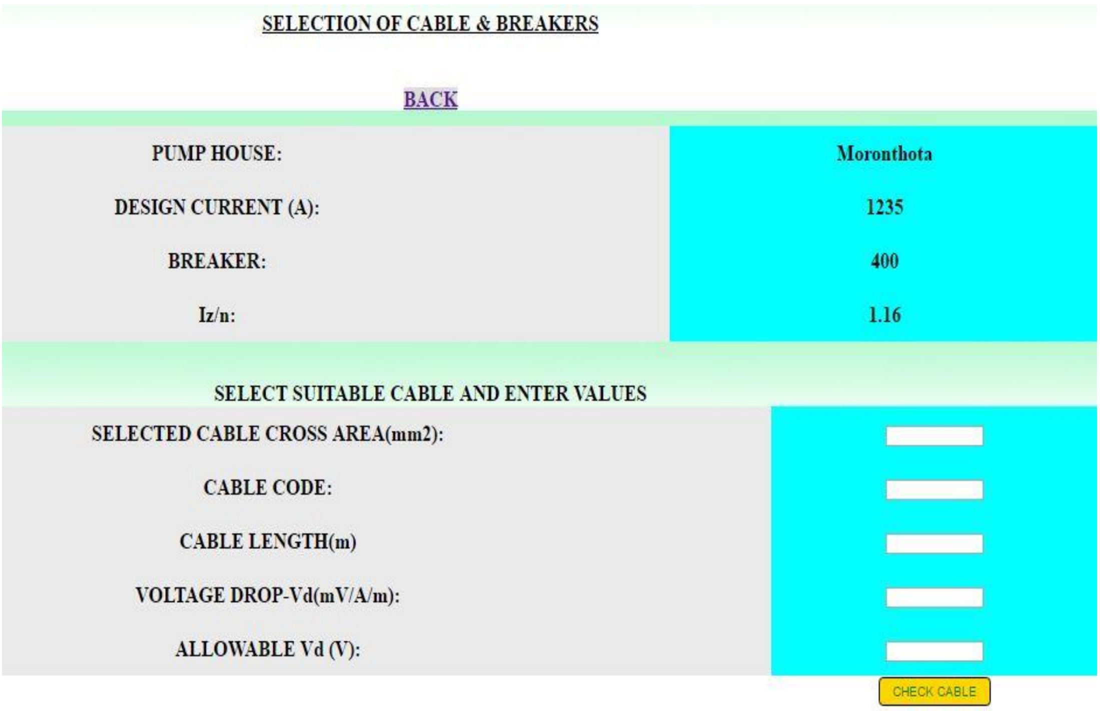


Figure 3.10: Data for checking voltage drop of the Power Cables

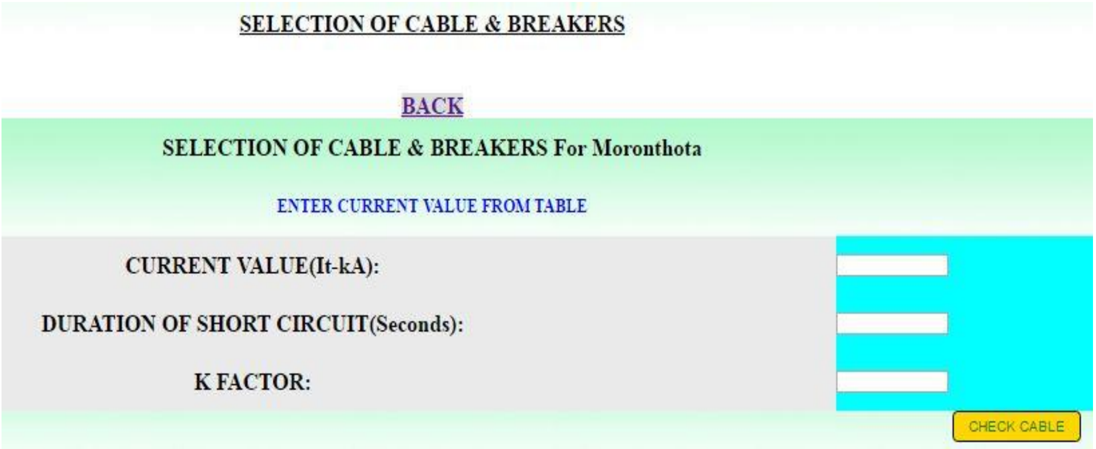


Figure 3.11: Checking for the short circuit conditions

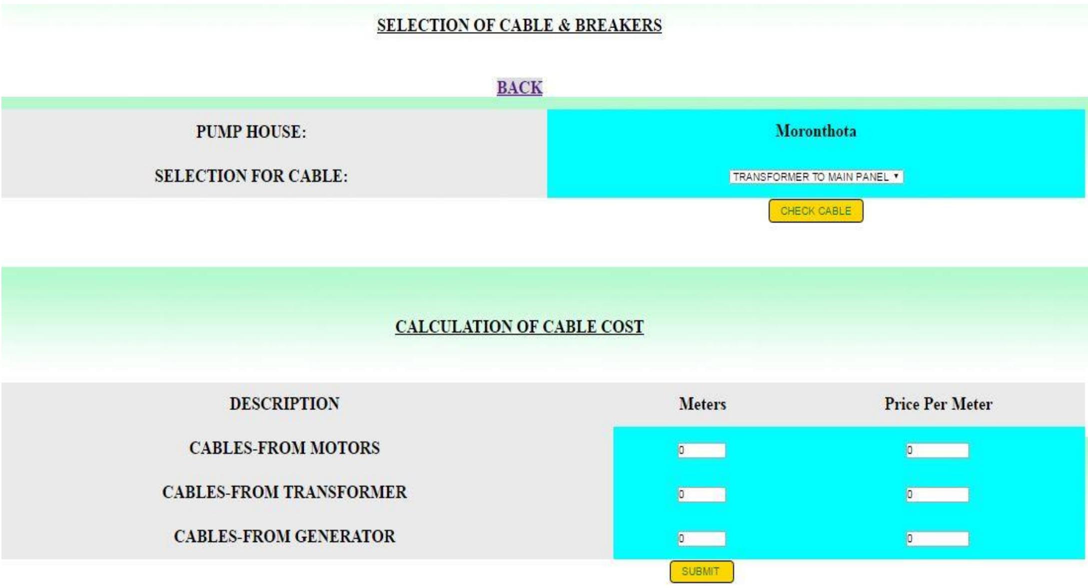


Figure 3.12: Calculation of cable cost

3.7 Selecting M&E Equipment in Pumping Station

The following figure summarizes the rank according to the combination of pumps selected. Then the most economical combination can be selected when designing a new pumping station.

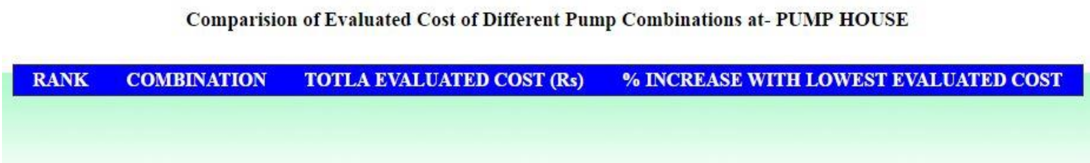


Figure 3.13: Ranking for different combinations of pumps

Chapter 4

ANALYZING OF EXISTING PUMPING STATIONS USING THE INTERFACES

4.1 Intake Pumping Station - Bambukuliya

Intake pumping station at Bambukuliya was analyzed by considering pump combinations 1duty & 1 standby, 2duty & 1 standby, 3duty & 1 standby and 4duty & 1 standby. The total evaluated cost has been calculated for each combination.

Table 4.1: Total Evaluated cost for combination 1 duty & 1 standby

1Duty &1Standby-NEW

ITEM	DESCRIPTION	QUANTITY	RATE	TOTAL CAPITAL(Rs)	PV ENERGY COST (Rs)	Total Evaluated Cost (Rs)
1	PUMP & MOTOR SET	2	16200000	32400000	46960400	79360400
2	POWER TRANSFORMER	1	1667000	1667000	0.00	1667000
3	STANDBY GENERATOR	1	5800000	5800000	0.00	5800000
4	CABLE MOTORS	60	11800	708000	0.00	708000
5	CABLE FROM TF	160	4400	704000	0.00	704000
6	CABLE FROM GEN	120	4400	528000	0.00	528000
	Total Evaluated Cost for the Major M&E Equipment in LKR					88767400

Table 4.2: Total Evaluated cost for combination 2 duty & 1 standby

2Duty &1Standby-PRESENT

ITEM	DESCRIPTION	QUANTITY	RATE	TOTAL CAPITAL(Rs)	PV ENERGY COST (Rs)	Total Evaluated Cost (Rs)
1	PUMP & MOTOR SET	3	10200000	30600000	57396100	87996000
2	POWER TRANSFORMER	1	1667000	1667000	0.00	1667000
3	STANDBY GENERATOR	1	5400000	5400000	0.00	5400000
4	CABLE MOTORS	90	6300	567000	0.00	567000
5	CABLE FROM TF	160	5400	864000	0.00	864000
6	CABLE FROM GEN	120	5400	648000	0.00	648000
	Total Evaluated Cost for the Major M&E Equipment in LKR					97142000

Table 4.3: Total Evaluated cost for combination 3 duty & 1 standby

Analysis of Different Combinations at:-BAMBUKULIYA PUMP HOUSE

3Duty &1Standby-NEW

ITEM	DESCRIPTION	QUANTITY	RATE	TOTAL CAPITAL(Rs)	PV ENERGY COST (Rs)	Total Evaluated Cost (Rs)
1	PUMP & MOTOR SET	4	4500000	18000000	57917800	75917800
2	POWER TRANSFORMER	1	1667000	1667000	0.00	1667000
3	STANDBY GENERATOR	1	4200000	4200000	0.00	4200000
4	CABLE MOTORS	120	3800	456000	0.00	456000
5	CABLE FROM TF	160	5400	864000	0.00	864000
6	CABLE FROM GEN	120	5400	648000	0.00	648000
	Total Evaluated Cost for the Major M&E Equipment in LKR					83752800

Table 4.4: Total Evaluated cost for combination 4 duty & 1 standby

4Duty &1Standby-NEW

ITEM	DESCRIPTION	QUANTITY	RATE	TOTAL CAPITAL(Rs)	PV ENERGY COST (Rs)	Total Evaluated Cost (Rs)
1	PUMP & MOTOR SET	5	3250000	16250000	62613900	78863900
2	POWER TRANSFORMER	1	1667000	1667000	0.00	1667000
3	STANDBY GENERATOR	1	4200000	4200000	0.00	4200000
4	CABLE MOTORS	150	3800	570000	0.00	570000
5	CABLE FROM TF	160	5400	864000	0.00	864000
6	CABLE FROM GEN	120	5400	648000	0.00	648000
	Total Evaluated Cost for the Major M&E Equipment in LKR					86812900

By considering the total evaluated cost of each duty and standby combination, cost comparison is carried out as shown in the following table. It indicates that the presently available combination has the highest total evaluated cost of all the combinations. This is not acceptable.

Table 4.5: Cost comparison for combinations - Intake at Bambukuliya

Comparision of Evaluated Cost of Different Pump Combinations at- BAMBUKULIYA PUMP HOUSE

RANK	COMBINATION	TOTLA EVALUATED COST (Rs)	% INCREASE WITH LOWEST EVALUATED COST
1	3Duty &1Standby-NEW	83752800	0
2	4Duty &1Standby-NEW	86812900	3.65
3	1Duty &1Standby-NEW	88767400	5.99
4	2Duty &1Standby-PRESENT	97142000	15.99

The summary of the analysis of the pumping station is given below.

Table 4.6: The summary of the analysis - Intake at Bambukuliya

Item description	Currently Available	Lowest Evaluated	Comment on currently available equipment
Pump Combination	2D 1SB	3D 1SB	Not recommended
Transformer (kVA)	160	160	Accepted
Generator(kVA)	182	158	Not recommended
Main Cables(mm2)	120x1Cx1	120x1Cx1	Accepted
Pump Cables(mm2)	50x3Cx1	25x3Cx1	Not recommended
Other Details	Most economical combination identified for this pumping system is 4 duty pumps and 1 standby pump		

4.2 Intake Pumping Station –Artigala Mawatha

Similarly, the total evaluated cost of each duty and standby combination is calculated and the cost comparison is carried out as shown in the following table. It indicates that the presently available combination is the 4thhighesttotal evaluated cost of all the combinations. This is not acceptable.

Table 4.7: Cost comparison for combinations – Artigala Mawatha

Comparision of Evaluated Cost of Different Pump Combinations at- ARTIGALA MW PUMP HOUSE

RANK	COMBINATION	TOTLA EVALUATED COST (Rs)	% INCREASE WITH LOWEST EVALUATED COST
1	4Duty &1Standby-NEW	25717200	0
2	5Duty &1Standby-NEW	26565400	3.3
3	3Duty &1Standby-NEW	35306600	37.29
4	2Duty &1Standby-PRESENT	47139300	83.3
5	1Duty &1Standby-NEW	48591500	88.95

The summary of the analysis of the pumping station is given below.

Table 4.8: The summary of the analysis – Artigala Mawatha

Item description	Currently Available	Lowest Evaluated	Comment on currently available equipment
Pump Combination	2D 1SB	4D 1SB	Not recommended
Transformer (kVA)	250	250	Accepted
Generator(kVA)	227	158	Not recommended
Main Cables(mm2)	240x1Cx1	150x1Cx1	Not recommended
Pump Cables(mm2)	35x1Cx1	25x3Cx1	Not recommended
Other Details	Most economical combination identified for this pumping system is 4 duty pumps and 1 standby pump		

4.3 Intake Pumping Station - Mawanella

Similarly, the total evaluated cost of each duty and standby combination is calculated and the cost comparison is carried out as shown in the following table. It indicates that the presently available combination is the 3rdhighesttotal evaluated cost of all the combinations. This is not acceptable.

Table 4.9: Cost comparison for combinations - Mawanella

Comparision of Evaluated Cost of Different Pump Combinations at- MAWANELLA PUMP HOUSE

RANK	COMBINATION	TOTLA EVALUATED COST (Rs)	% INCREASE WITH LOWEST EVALUATED COST
1	3Duty &1Standby-NEW	20047300	0
2	4Duty &1Standby-NEW	20744200	3.48
3	5Duty &1Standby-PRESENT	21065100	5.08
4	2Duty &1Standby-NEW	22004900	9.76
5	1Duty &1Standby-NEW	32565900	62.45

The summary of the analysis of the pumping station is given below.

Table 4.10: The summary of the analysis - Mawanella

Item description	Currently Available	Lowest Evaluated	Comment on currently available equipment
Pump Combination	5D 0SB	2D 1SB	Not recommended
Transformer (kVA)	160	160	Accepted
Generator(kVA)	None	136	
Main Cables(mm2)	70x1Cx1	70x1Cx1	Accepted
Pump Cables(mm2)	25x3C	25x3C	Accepted
Other Details	Most economical combination identified for this pumping system is 2 duty pumps and 1 standby pump. No any standby pump or standby generator available. Therefore reliability of the existing pumping system is very low.		

Chapter 5

VALIDATION OF THE INTERFACES

5.1 Introduction

In chapter 5, validation of the software interfaces is carried out by using high lift pumping station at Morontota and high lift pumping station at Negombo. These pumping stations are identified as few of the most efficiently operating pumping stations in NWD&DB. When the analysis was done with the software interfaces, it has been observed that the presently available combinations of these pumping stations are complying with the most economical combination selected. Additionally, presently available ratings of pump motors, transformers, standby generators, power cables and circuit breakers are also complying with the selection carried out by the software. Therefore, analyzing high lift pumping station at Morontota and high lift pumping station at Negombo will provide sufficient validation to the software interfaces used.

5.2 High Lift Pumping Station - Morontota

Similarly, the total evaluated cost of each duty and standby combination is calculated and the cost comparison is carried out as shown in the following table. It indicates that the presently available combination has the lowest total evaluated cost of all the combinations.

Table 5.1: Cost comparison for combinations - Morontota

Comparision of Evaluated Cost of Different Pump Combinations at- MORONTHOTA PUMP HOUSE

RANK	COMBINATION	TOTLA EVALUATED COST (Rs)	% INCREASE WITH LOWEST EVALUATED COST
1	2Duty &1Standby-PRESENT	73068500	0
2	1Duty &1Standby-NEW	75002200	2.65
3	3Duty &1Standby-NEW	83999600	14.96
4	4Duty &1Standby-NEW	87423300	19.65

The table 5.1 indicates that the presently available combination is the same as the lowest evaluated combination selected by the software. This is acceptable and it provides evidences to support the validation for the software interfaces. Further these pumps are operating at design duty points and they operate with lower specific energy consumption.

The summary of the analysis of the pumping station is given below.

Table 5.2: The summary of the analysis - Morontota

Item description	Currently Available	Lowest Evaluated	Comment on currently available equipment
Pump Combination	2D 1SB	2D 1SB	Accepted
Transformer (kVA)	1000	1000	Accepted
Generator(kVA)	820	820	Accepted
Main Cables(mm2)	300x1Cx3	300x1Cx3	Accepted
Pump Cables(mm2)	95x1Cx1	95x1Cx1	Accepted
Other Details	This pumping station is complying the currently available combination with the pump combination having the lowest evaluated cost selected by the software.		

5.3 High Lift Pumping Station - Negombo

Similarly, the total evaluated cost of each duty and standby combination is calculated and the cost comparison is carried out as shown in the following table. It indicates that the presently available combination has the lowest total evaluated cost of all the combinations.

Table 5.3: Cost comparison for combinations - Negombo

Comparision of Evaluated Cost of Different Pump Combinations at- NEGOMBO HL PUMP HOUSE

RANK	COMBINATION	TOTLA EVALUATED COST (Rs)	% INCREASE WITH LOWEST EVALUATED COST
1	2Duty &1Standby-PRESENT	212533000	0
2	1Duty &1Standby-NEW	217440000	2.31
3	3Duty &1Standby-NEW	219183000	3.13
4	4Duty &1Standby-NEW	237894000	11.93
5	5Duty &1Standby-NEW	249391000	17.34

The table 5.3 indicates that the presently available combination is the same as the lowest evaluated combination selected by the software. This is acceptable and it provides sufficient evidences to support the validation of the software interfaces.

The summary of the analysis of the pumping station is given below.

Table 5.4: The summary of the analysis - Negombo

Item description	Currently Available	Lowest Evaluated	Comment on currently available equipment
Pump Combination	2D 1SB	2D 1SB	Accepted
Transformer (kVA)	400	400	Accepted
Generator(kVA)	500	500	Accepted
Main Cables(mm2)	300x1Cx2	300x1Cx2	Accepted
Pump Cables(mm2)	300x3Cx1	300x3Cx1	Accepted
Other Details	This pumping station is complying the currently available combination with the pump combination having the lowest evaluated cost selected by the software.		

Chapter 6

CONCLUSION AND RECOMMENDATION

Pumping works incorporates diversified fields of technologies including mechanical, civil and electrical/instrumentation engineering. All the above items should be taken into consideration in every step of planning and design of the pumping works so that the most effective means to meet with the specific purpose may be materialized.

Main objective of the research work described in this thesis was to develop a software guided systematic approach to electromechanical designs of new pumping stations in the NWS&DB taking cost, performance, service, and maintenance factors in to consideration. This is a much needed tool for the engineers of the NWS&DB when it comes to a designing new pumping station, or negotiating the designs forwarded by foreign contractors. Majority pumping stations in the NWS&DB have been built by foreign contractors with designs tested in some other parts of the world without taking serious considerations to the local needs and constraints. It can be concluded that the objectives of the work have been achieved and fully functional software base design guidance has been developed to design new pumping stations of NWS&DB.

The total flow rate, static head of pumping system, number of duty pumps and standby pumps are the basic input to this software. Details of piping and accessories are to be provided additionally to calculate the total head and the NPSH availability. Web base software provided by the pump manufacturers are then used to select most efficient pumps for the particular application. Load list is prepared with the details available and design calculations for selecting appropriate power transformers, standby generators, power cables and circuit breakers are performed with the use of this software. Additionally, operational cost calculation is also carried out in order to rank and select the optimum combination of pumps

The software was validated on few selected pumping stations, and they reveal the levels of improvements that could have been achieved. As a further work, the aspects of civil engineering can also be incorporated to the program to make it more comprehensive design software.

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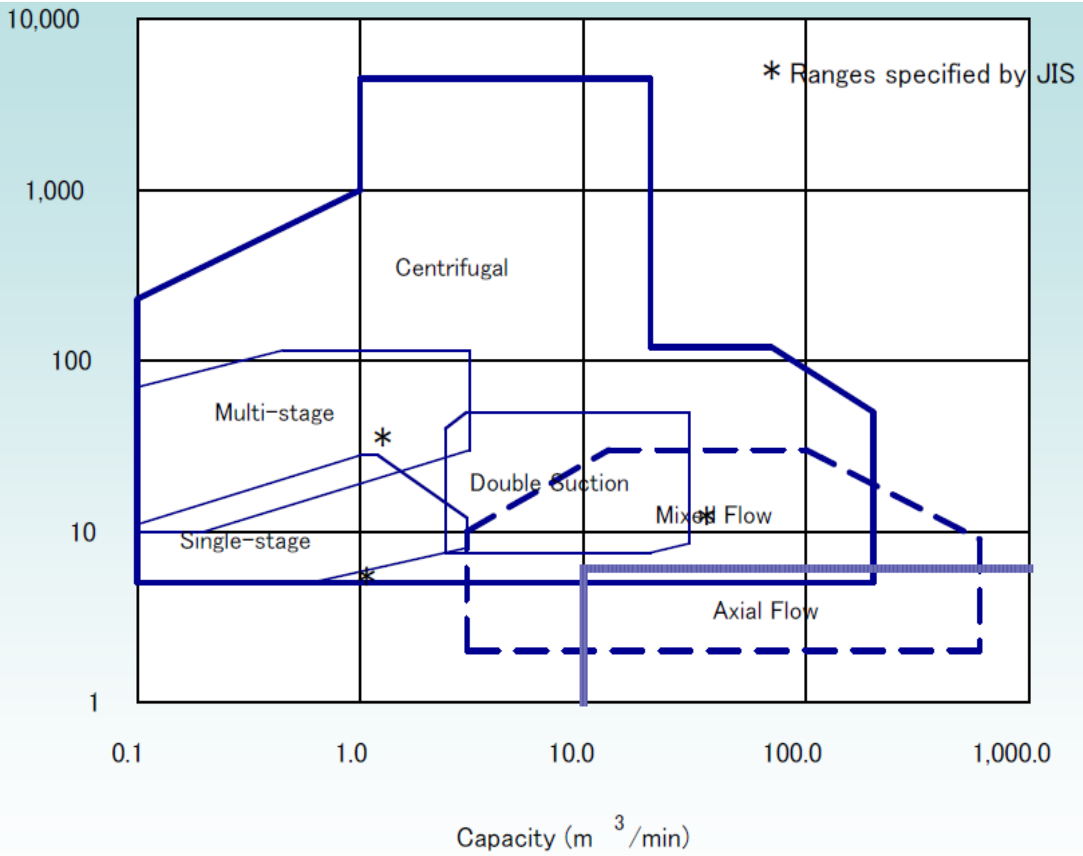
LIST OF APPENDICES

APPENDIX 1: Range of Applications



APPENDIX 2: General algorithm for Selecting M&E Equipment in Pumping Stations.