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Estimating Agricultural Demand Side Management(AgDSM) Potential

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Abstract

The paper focuses on estimating the AgDSM potential by analyzing the irrigation water requirement of major crops falling under Ramnagar substation in Jalna district of Maharashtra state. Blaney- Criddle formula is used to calculate the potential evapotranspiration rate of the Jalna District. Major crops in the area are calculated from the area under different crops. Indian Meteorological Department provides district wise monthly rainfall data. These all are used to calculate the effective rainfall, crop water requirement, Irrigation water requirement, net irrigation water requirement and the volume of the water required for the major crops in the area during the entire cropping season. The discharge head was determined from the discussion with farmers, water level in the area and the piping system used. On the basis of water required and discharge head the rating of pump set required is determined from BEE's star rating list of pump set. The distribution system upgrades are also suggested to insure good voltage profile.

Keywords- *DSM, Agricultural Demand Side Management, HVDS*

1. Nomenclature

Ag: Agricultural

DSM: Demand Side Management

BEE: Bureau of Energy Efficiency

HVDS: High Voltage Distribution System

LT: Low Tension

2. Introduction

In India more than 50% of fresh water and around 30% of electricity are consumed for agricultural use, causing an extreme shortage. The problem of water is more serious as the water level is continuously decreasing. Green revolution has made India able to feed its growing population but has also increased the demand of water and electricity. Most of the farms in the country are rain fed, hence the monsoon plays important role in agricultural while ground water becomes reliable source. Due to the poor economic condition of farmers and its political advantages, government is giving power to the farmers at subsidized rates. [9]

There are various fresh water sources like rivers, dams, lake or ponds and ground water. From all the above ground water is available everywhere and supplies most of the agricultural water requirement. Farmers being illiterate and because of subsidized power rates, use of oversized pumps to extract water from growing depths is common. The high friction foot valve and inefficient piping system are generally preferred as they are economical. The energy consumption for irrigation in India can be lowered to half if the conventional pump sets are replaced with matching energy efficient BEE 5 or 4 stars rated pump sets.

3. Electricity Distribution System in Jalna District

Figure 1. Study area

The Jalna district of Maharashtra state is situated at 19^{o}1 north to 21^{o}3 North latitudes and 75^{o}4 East to 76^{o}4 East longitude. The Ramnagar substation is located nearly 18 km from the district place. Two agricultural separated feeders namely Ramnagar Ag and Bhatepuri Ag coming out from the substation are selected for project study. Fig 1 shows the location of the district in state map. [12]

Electricity is delivered to consumers through 11 kv feeders coming out from the 33 KV substation. The 11 KV feeders are then divided into sub branches of 11 KV to carry power to the load points. Before supplying the load, a distribution transformer steps down the voltage from 11 KV to 440 V. Individual customers are connected to 440 V low tension (LT) lines to obtain 415 V for three phase supply and at 230 V for single phase supply.

Ramnagar substation is 33/11 kV substation having six 11 kV outgoing feeders namely Gaothan, S. Ginning Express, Deolgaon Raja Water Supply Express (D.R.W.S.Exp), Bhatepuri Agricultural, Ramnagar Agricultural and Karkhana. The two feeders namely Ramnagar Ag and Bhatepuri Ag are supplied at 11 kV from 33/11 kV substations of Maharashtra State Electricity Distribution Company Limited (MSEDCL). Both the feeders are isolated agricultural feeders. Almost all the agriculture connections under the substation are connected to these feeders.

Table 1. Segregation of metered and un-metered consumers

Metering Status	Agricultural Connections
Metered	**370**
Un-metered	**592**
Total	**962**

Most of the pump sets are un-metered. Around 592 numbers of pump sets out of 962 (≈ 62%) at the two feeders are unmetered and have been charged on the basis of connected HP load whereas 370 pump sets are installed with energy meters

The single line diagram of the Ramnagar substation is shown below.

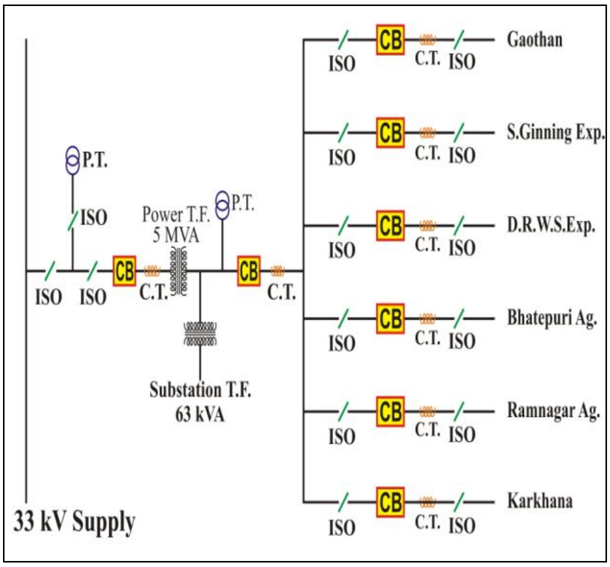

Figure 2. Single Line Diagram of Ramnagar Substation

4. Cropping Pattern

Kharif and Rabi are the two main cropping seasons in the district. Kharif season starts in early June and ends in November. The main crops in this season are Cotton, Ground –nut, Bajra, tur, maize, Mug etc. Rabi Season starts in November and ends in March –April. The main crops are Jowar, wheat and gram.As the Jalna District has sugar factories, sugarcane is the leading cash crop of the farmers. Table –II shows the area under different crops.

Table 2. Area under different crops

Crop Type	Area under Different Crops				Total	
	Ramnagar Ag		Bhatepuri Ag			
	Acres	%	Acres	%	Acres	%
Jowar	642	9.39	452	10.08	1094	9.66
Bajra	132	1.93	52	1.15	184	1.63
Wheat	554	8.10	321	7.15	875	7.73
Corn	59	0.86	0	0	59	0.52
Sugarcane	2634	38.5	1821	40.61	4455	39.4
Groundnut	642	9.39	240	5.35	882	7.79
Harbhara	51	0.74	68	1.51	119	1.05
Kapas	1043	15.3	857	19.11	1900	16.8
Vegetables	361	5.28	114	2.54	475	4.20
Sun flower	254	3.71	39	0.86	293	2.59
Pulses	420	6.14	460	10.25	880	7.77
Others	45	0.65	60	1.33	105	0.93
Total	**6837**	**100**	**4484**	**100**	**11321**	**100**

The crops in the red circles are major crops taken on larger area. On overall basis, the farmers in the both feeder region have sugarcane, jowar and cotton as the major crops.

5. Crop Water Requirement

The main objective of the study is centered on calculating the correct size of pump set required for the given farm. The main use of electrical energy in the agricultural area is for the pump sets to irrigate the farm crops. Some other agricultural application may also need electrical energy. This can be formulated as –

Electrical Energy requirement = consumption by pumps + X

Where, X = energy consumption in agricultural area other than pumping application which is generally 0.02 to 0.7 times the electrical energy requirement.

Thus the majority of energy is consumed by the pumps. The water needed to be discharged decides rating of pump which ultimately decides consumption of energy by pump. So for a crop it is important to determine the water needed to be discharged. The water to be discharged depends on following factors-

a) Crop pattern of the area

This includes the various crops taken in the area, the climatic conditions during crop, the season of crop, crop factor of the crop taken *etc.*

b) Type of soil

The type of soil decides the water holding capacity of the soil. This actually gives the measure of how much of the total water given, the soil can retain.

c) Effective rainfall of the area

This is that amount of total rainfall which is actually absorbed by the soil and is available as groundwater. It determines various factors governing the agricultural system like- seasonal irrigation water requirement by crop, water availability head *etc.*

The water requirement of crop can be calculated by following procedure.

The evapotranspiration for an area is calculated by Blaney- Criddle formula as shown below

$$ET_0 = \rho*(0.46*T_{mean} + 8)$$

Where, ET_0 is the potential Evapotranspiration rate (in mm/day), ρ mean daily percentage of annual day time hours, T_{mean} is the mean daily temperature.

The crop water requirement (CWR) values for a particular crop can be calculated by multiplying the potential evapotranspiration rate at a time of the area at a time to the crop factor (Kc) of the crop at that growth stage. [1], [5], [7]

$$CWR = Kc * ET_0$$

The value of Kc for a crop varies according to its growth stage (*i.e.* initial, middle and end).

FAO (Food and Agricultural Organization) has given a formula to calculate the Effective rainfall as given below [6], [1]

$$ER = 0.0011x^2 + 0.4422x$$

Where, ER and x are effective rainfall in mm and total rainfall in mm respectively for a particular area under consideration.

The irrigation water requirement (IR) depends on the effective rainfall (ER) and the crop water requirement (CWR). IR is the subtraction of effective rainfall from the crop water requirement. [1], [7]

$$IR = CWR – ER$$

The total water given in the farm is not completely available for the crops as some losses occur. These losses are assumed to be around 35% of the irrigation water need. Thus the total or net irrigation water requirement is given by

$$NIR = IR + LOSSES - Z$$

Where, Z is the irrigation water requirement fulfilled by other sources not requiring pumping application (from lake, pond or dam through canals) which is around 9% of IR but varies greatly on the location under study.

The water needed to be discharged Q (in million cubic meters / month) depends on the NIR and crop acreage value and is obtained by multiplying irrigation water requirements with crop acreage values (CAV). [1]

$$Q \text{ (million m}^3\text{/ month)} = NIR * CAV$$

6. Results Obtained

The daily evapotranspiration rate (ET_0) can be calculated using above equations. The values obtained are in mm per day and are multiplied by the number of days in month to obtain monthly values. The values obtained are shown in the following table.

Table 3. Values of monthly potential evapotranspiration

Month	Daily ET_0 (in mm)	Monthly ET_0 (in mm)
Jan	9.27	278.1
Feb	11.34	340.2
Mar	14.16	424.8
Apr	17.92	537.6
May	19.73	591.9
Jun	14.01	420.3
Jul	11.29	338.7
Aug	10.26	307.8
Sep	11.06	331.8
Oct	11.74	352.2
Nov	10.43	312.9
Dec	8.17	245.1

Crop water requirement of the major crops taken in their dominating season in the district is presented below. The values given are on monthly basis during the various stages of crop growth.

Table 4. Crop water requirement

Month	Crop Water Requirement (in mm)		
	Sugarcane	Jowar	Cotton
Jan	111.24	-	-
Feb	238.14	-	-
Mar	403.56	-	-
Apr	53.76	-	-
May	680.68	-	-
Jun	483.34	168.12	189.13
Jul	389.50	237.09	254.02
Aug	353.97	215.46	353.97
Sep	381.57	315.21	381.57
Oct	405.03	334.59	264.15
Nov	265.96	344.19	234.67
Dec	159.31	-	-

Irrigation water requirement is calculated from the crop water requirement and effective rainfall. It is the difference of effective rainfall and crop water requirement.

Table 5. Irrigation water requirement

Month	IR (in mm)		
	Sugarcane	Jowar	Cotton
Jan	111.24	-	-
Feb	237.12	-	-
Mar	403.56	-	-
Apr	53.72	-	-
May	679.84	-	-
Jun	465.48	150.25	171.26
Jul	234.88	82.46	99.40
Aug	223.38	84.86	223.38
Sep	327.80	261.44	327.8
Oct	399.00	328.56	258.12
Nov	265.97	344.19	234.67
Dec	159.32	-	-

The water given to the farm is not completely available to crops due to losses. These losses are assumed to be 35% of irrigation water requirement. The net irrigation water requirement for all three major crops is calculated and given below.

Table 6. Net irrigation water requirement

Month	Net Irrigation Water Requirement (in mm)		
	Sugarcane	Jowar	Cotton
Jan	150.17	-	-
Feb	320.11	-	-
Mar	544.81	-	-
Apr	72.52	-	-
May	917.78	-	-
Jun	628.39	202.84	231.20
Jul	317.09	111.33	134.19
Aug	301.56	114.57	301.56
Sep	442.53	352.94	442.53
Oct	538.65	443.55	348.46
Nov	359.05	464.65	36.81
Dec	215.08	-	-

The net irrigation water requirement was multiplied with cropped area of each crop to estimate the volume of water (in m^3/month) required for the entire growing season which is then converted to discharge of water (in liter per second) needed.

Table 7. Volume of water required

Month	Q (in liter per second)		
	Sugarcane	Jowar	Cotton
Jan	1.17	-	-
Feb	2.49	-	-
Mar	4.25	-	-
Apr	0.57	-	-
May	7.16	-	-
Jun	4.91	1.58	1.80
Jul	2.48	0.87	1.05
Aug	2.36	0.89	2.35
Sep	3.46	2.75	3.46
Oct	4.21	3.46	2.72
Nov	2.81	3.63	2.47
Dec	1.68	-	-

The value of discharge needed for a crop varies with growth stage the maximum value of discharge is considered for each crop indicated by the red circles. It is seen that, most of the farmers in these two feeders are having cultivable land divided in small sections for each crop. So for convenience let us take the cropped area of 5 acres for each crop per farm.

The water level declines in the summer season whereas post monsoon water level moves up, water level variation is in the range of 7 to 18 m.

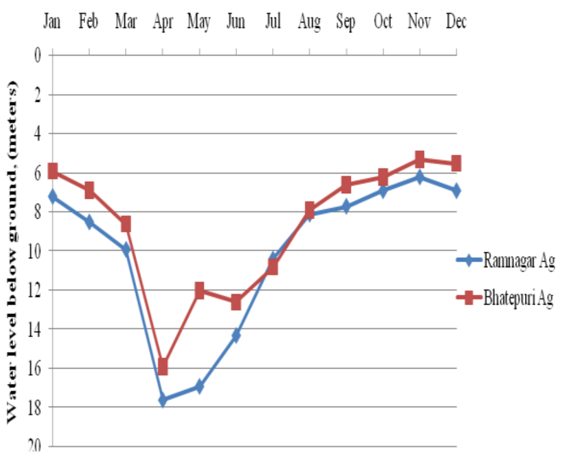

Figure 3. Variation of water level below ground

The net head for discharge is found to be varying from 45m to 65m. Assuming head to be 65m, let us compare the discharge in liter per second and head in meter needed for these crops in the study area.

The BEE 4 or 5 stars rated pumps which suits here can be obtained from the BEE star rated list of pumps which provides the detailed information of pump like manufacturer's name, model number, discharge head in meters, discharge in lps, number of stages, rating in kW, efficiency and the BEE star rating. As we know both head and discharge required for the crops, on the basis of that we can easily select the pump suitable for our application. [10]

Table 8. Pump rating

Crop	Pump Rating	
	kW	HP
Sugarcane	5.5kW	7.5HP
Jowar	3.7kW	5HP
Cotton	2.6kW	3.5HP

Energy efficient pump sets are relatively more sensitive to voltage fluctuations than the conventional. The current LT distribution system has more voltage fluctuations and needs to be upgraded to HVDS system before installing energy efficient pumps.

7. Distribution System Upgrades

The longer length of LT line used to supply the agricultural consumers separated from each other by large distances. The longer length of LT lines increases the cases of energy theft. Along with the above problem the feeder lines are having more connections than their capacity; this overloading leads to drop in voltage increasing towards the end of the line. The voltage available to the consumer end varies from 400V to 310V. [9]

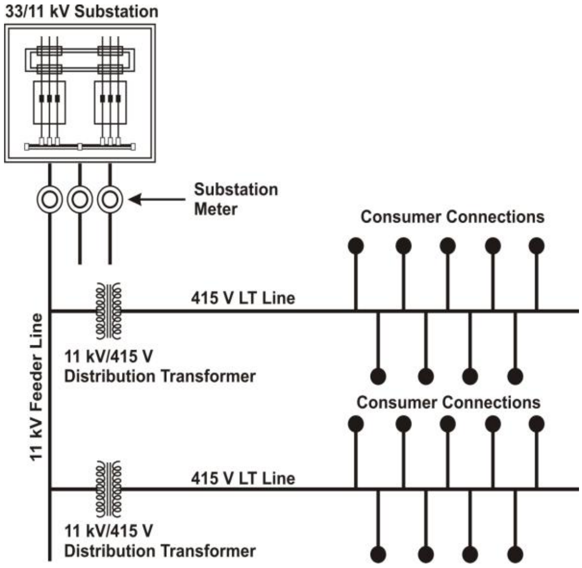

Figure 4. Present LT Electricity Distribution Structure [9]

The above mentioned problems of LT distribution system can be rectified to some level by upgrading it to HVDS.

The HVDS network has several technical benefits over the current LT distribution system like minimum technical losses, improved voltage profile and puts restriction on energy theft. In HVDS, 11 kV line is brought up to end user and the currently working higher rating transformers will be replaced by smaller rating distribution transformers supplying either individual consumer or a small group of consumers. To know the exact energy saving achieved, all the agricultural connections should be metered. HVDS structure that can be implemented is shown in Fig.4. [9], [11]

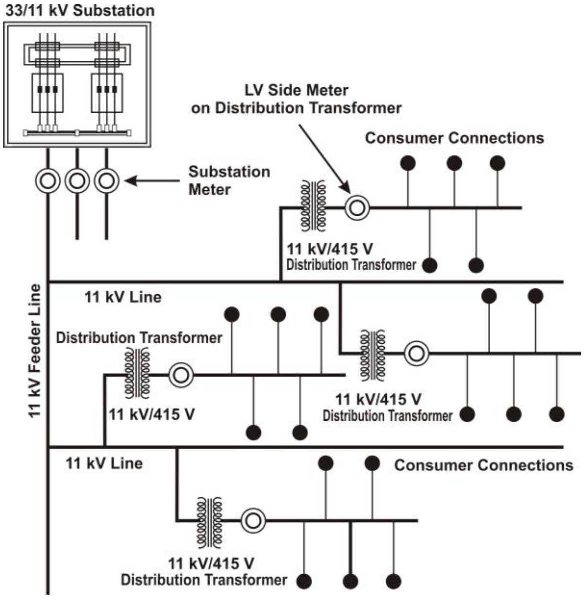

Figure 5. HVDS Structure for Electricity Distribution [9]

8. Conclusion

The discharge needed in liter per second. The discharge head is determined from the discussion with farmer. On the basis of these the proper rating of pump required can be selected from BEE's list.

If all the conventional pump sets in the study area are replaced with the energy efficient BEE 5 or 4 star rated pump sets then the energy saving that will occur is estimated in the following table IX.

Table 9. Estimated energy saving

Hp Rating	No. of Pump Sets	Total Energy Consumption		Total Energy Saving (kWh)
		Conventional pumps(kWh)	Energy efficient pump(kWh)	
3HP	235	1193800	817800	376000
5 HP	183	1350540	852780	497760
7.5 HP	243	2614680	1380240	1234440
10 HP	113	2264520	537880	1726640
12.5 HP	124	2296480	1445840	850640
15 HP	43	913320	608020	305300
20 HP	21	571620	356160	215460
Total		11204960	5998720	**5206240**

Thus around 45% of energy saving is achieved per year in this area which is appreciable amount of energy. As energy saved is energy generated; this will help us on managing the demand.

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