Lift Irrigation Projects for Demad Side Management and conseqeuent benefits to the Home State

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Abstract: **Lift irrigation is a method of supplying water to the crops by pumping water using power intensive synchronous machines to an upper altitude terrain or reservoir. These loads depend on the availability of water and are predominant during monsoon period. Incidentally, this period is also the major wind generation season in India. These synchronous loads can be made flexible and can provide near instantaneous active and reactive power response, similar to hydel plants. This paper presents how these loads can be exploited for better grid operation, facilitating RE integration, reducing instances of RE curtailment, using study results from an optimization software. The commercial gains to the home state have also been presented.**

I. INTRODUCTION

Indian electricity grid is one of the largest grids in the world with an installed capacity of more than 330GW [1]. Indian electricity grid synchronously operates in five different regions namely northern, eastern, western, southern and north-eastern regions. It has inter-connections with Nepal, Bangladesh, Myanmar and Bhutan. Thermal power is the main source of electricity generation with around 220GW [1] of installed capacity. The share of renewable energy (RE) sources is around 18%, with an installed capacity of more than 62GW. Government of India has committed to reduce its carbon emissions at Paris Climate Summit and has a target of installing 175GW of Renewable Energy by 2022. This constitutes 100GW [2] of Solar, 60GW [2] of Wind and 15GW [2] of Small Hydro and Biomass. Of the total 160GW of Solar and Wind, Southern Region (SR) has a target of nearly 33% comprising 26GW [2] of Solar and 28GW [2] of Wind. Integrating such a huge quantum of RE is quite challenging as RE is characterized with uncertainty, variability and intermittency.

Lift irrigation projects are predominant in the Deccan plateau region of Indian sub-continent. This paper presents how these LI (Lift Irrigation) loads can aid better grid operation, thereby facilitating RE penetration. The economic benefit to the lift irrigation project owner is also presented.

II. RE INTEGRATION

Integrating large RE comes with its challenges of variability & uncertainty and Utilities are confronted with the need to maintain the load-generation balance in real time. Key to RE integration is often referred to as requirement of Flexi Watts. To maintain perfect balance between supply and demand of the power, system operator uses various resources like flexing the conventional generation & utilizing Demand Response (DR). Any difference between these two can threaten grid stability besides causing fluctuations in the frequency. They can lead to huge commercial implications, as deviations are charged w.r.t frequency in the settlement mechanism in vogue in India, called ABT [3]. Fast changes in RE generation could mean that the ramp requirement from the conventional generation can be very steep which forces the Utilities to keep fast acting reserves always ready. These reserves constitute hydro, gas, storage and coal based thermal generation to certain extent. Other means to balance Load-Generation is through Demand Response (DR). In DR systems, load can be controlled by the utilities from a centralized location by providing suitable financial compensation.

III. OVERVIEW OF LIFT IRRIGATION PROJECTS

Deccan plateau of the Indian sub-continent is characterized by huge river belts with uneven altitude of land. There is abundant availability of water, but limited possibility of natural irrigation facilities due to differential altitude in terrain. Governments of these States have conceived LI projects to lift water to certain altitude and made a network of canals to enable free flow via gravity. These are monsoon fed and run depending on availability of water in the river. Typically, these schemes run between July and November [4]. They help in maximum utilization of rain water before entering sea and in some cases they help in managing flood in the downstream areas. Amount of water to be pumped is decided by the irrigation authorities based on inflows, excess after catering to local needs and requirement of water for irrigation purposes at different levels. Sample operation of a lift irrigation project in Andhra Pradesh state of SR is given in Fig 1.

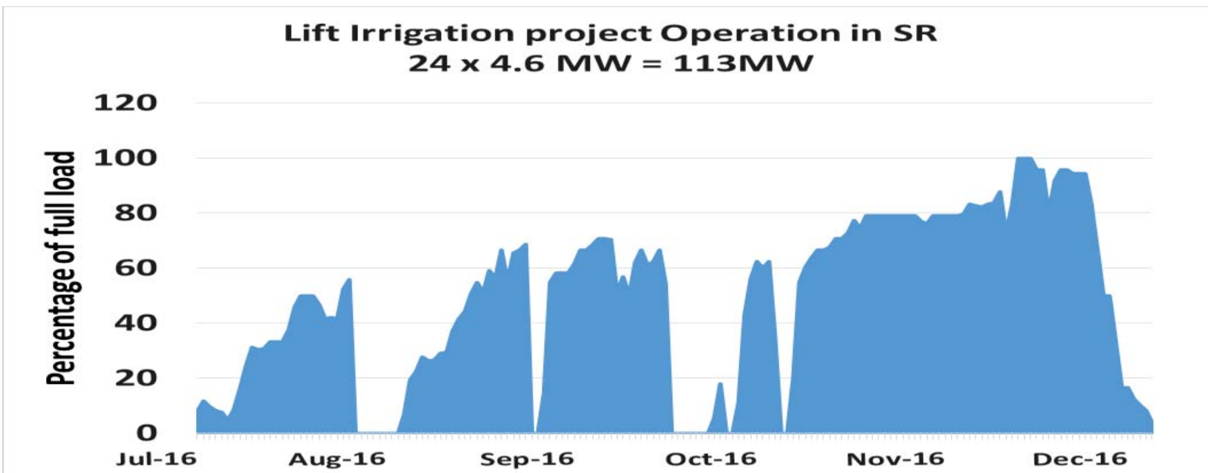

Fig 1: A Lift Irrigation project operation in Southern Region

Depending upon the altitude and terrain, these projects have different stages. At each stage, water is lifted to an altitude of around 30-35m. This arrangement is similar to a tandem hydro, where water level at each stage depends on the operation of the previous stage. Sample schematic diagram of Handri-Neeva Ph-1 in Andhra Pradesh is shown in Fig 2. Balancing reservoirs are provided between every 2-3 stages. Altitude/Head, availability of water and discharge requirement decide the size of each motor and the number of motors.

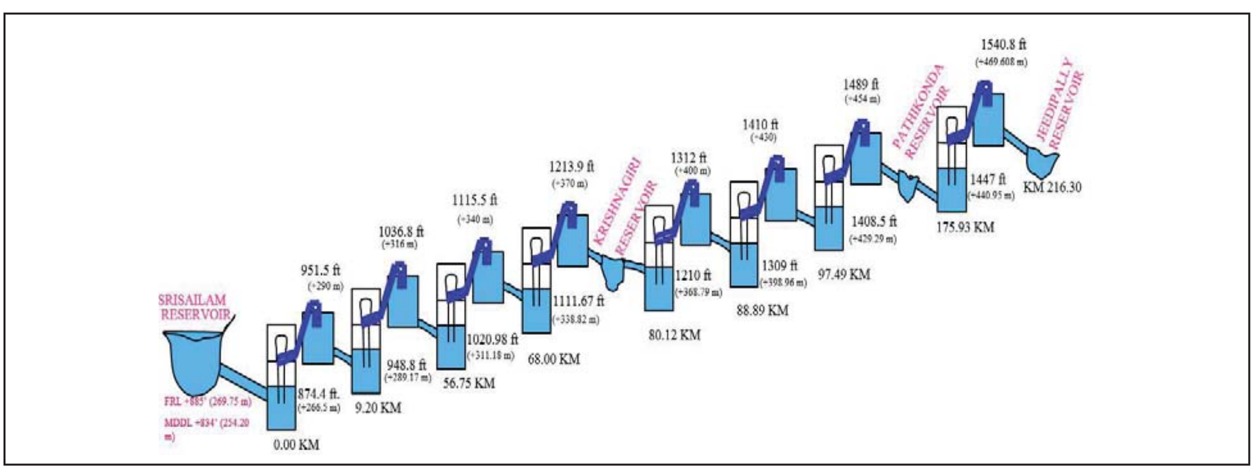

Fig 2: Schematic diagram of Handri-Neeva Ph-1 Lift Irrigation Project (Multi Stage)

As on date, capacities of these motors are in range of few 1-5 MW and capacity at each of the station varies from 10-150MW. Details of major lift irrigation projects commissioned in different states of Southern Region is given in Table-1.

In the next 3-5 years, lift irrigation projects are on the anvil on a very large scale in various states of Southern India and Maharashtra. These have synchronous machines of capacity ranging from 30-150MW at different locations. Details of power requirement of major upcoming projects are given in Table 2.

Table 1: List of major Lift Irrigation projects operational in SR

Sl No	Name of the project	Capacity
1	Handri –Neeva Ph 1 (AP)	458MW[5]
2	Kalwakurthy (TS)	450MW [6]
3	Pattiseema (AP)	113MW[7]

Table 2: Upcoming Lift Irrigation projects

Sl No	Name of the project	Capacity
1	Kaleswaram (TS)	4300 MW[8]
2	Palamuru-Rangareddy (TS)	3635 MW[8]
3	Devadula (TS)	484 MW [9]
4	Uttarandra Sujala Sravanthi (AP)	339 MW [10]
5	Handri Neeva Ph -2 (AP)	284 MW [11]

There are many other small scale projects proposed. A conservative estimate of the total installed lift irrigation projects could be around 10-12GW by 2022 in Southern Region of India.

IV. ELECTRICAL CHARECTERISTCS OF LIFT IRRIGATION PROJECTS

Lift irrigation projects primarily use synchronous machines owing to their efficiency and size. Some of the characteristics of LI projects are discussed below.

1) Being large synchronous machines, they help in increasing system inertia, improving the short circuit level of local bus.
2) Immediate response, fast ramps, similar to that of a hydroelectric plant.
3) Few machines can be run under partial load, by valve control. This can be used for providing Demand Response (DR).
4) Demand Response can also be achieved by switching the machines on & off other than operating at partial load. Theoretically, typical machine with 4-5MW capacity can be switched 2-3 times in an hour and a machine of 100MW can be switched around 5-10 times a day.
5) As synchronous machines, these can provide reactive support, stabilizing the local voltages. These LI loads are often located at weak buses at remote areas where Reactive requirements exist.
6) These machines are equipped with SCADA and can be visualized & controlled from a centralized location.
7) These machines can also provide reactive power support during fault conditions, thus reducing voltage dip in nearby buses.

Thus, Lift irrigation projects are versatile loads and can be of great help to the system operator in balancing the grid.

V. HARNESSING THE LIFT IRRIGATION PROJECTS FOR BETTER GRID OPERATION

a) Active Power support

As shown in Fig 1, these projects operate at full load for very limited period of time in the whole season. This feature can be used to schedule these loads at different part of the day, keeping the amount of water to be pumped constant. As discussed in Section III, many projects have balancing reservoirs after 2-3 stages, which can store water for a period of 1-1.5 days. This feature can be exploited for providing grid support services. Co-ordination with irrigation department is required for details regarding quantity of water to be pumped on each day, which can enable the system operator to schedule these loads as per requirement of grid, within the LI constraints. The characteristics explained earlier can be exploited by the grid operator for efficient management of the grid. By utilizing LI projects, system operator can achieve large demand response from relatively very less devices. Relatively large chunk of demand response can be obtained at a small location with little effort.

Proper scheduling of these loads can assist system operators in addressing the fast ramping requirements dictated by RE. Effective utilization of LI loads can improve the quality of power and can save a lot in terms of deviation charges. As on date, ancillary services are being despatched from thermal stations. Energy desptahced under ancillary services in SR would be around 30-40MU [12] per month for regulation up ancillary service and 5-10MU [12] for regulation down ancillary service. This could increase many fold with the increase in penetration of RE. Being fast acting machines, the flexibility available in LI loads can be used in despatching ancillary services too. This can be considered as relatively greener, as reduction of LI loads during contingencies can replace the need for increasing thermal generation. Based on availability and requirement of water, part of these can also considered in maintaining regional spinning reserves. LI loads are predominant during monsoon period of the country which is also the peak wind generation season in India. As requirement of balancing services during the above period is higher than other part of the year, effective utilization of LI projects can reduce RE curtailment.

b) Reactive Power support

These LI loads helps in maintaining the bus voltages by providing reactive support. These are equipped with Automatic Voltage Regulator (AVR) and the excitation of the machines will get adjusted according to the bus voltage. Fig 3 shows the capability of the LI loads for providing reactive power support. From Fig 4, it can be understood that under no load/lightly loaded conditions, bus voltage may be high. Operation of these synchronous machines under condenser mode during these conditions can help in maintaining voltages within limits.

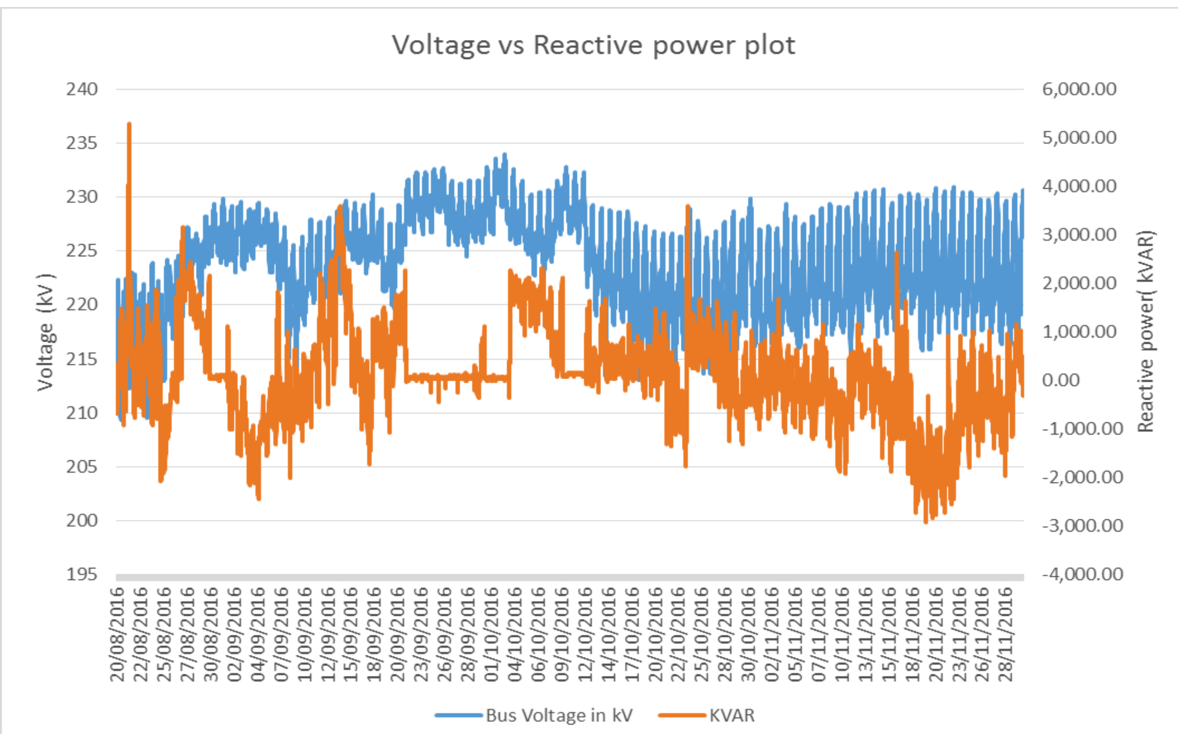

Fig 3: Voltage vs Reactive power plot of a Lift Irrigation project in SR

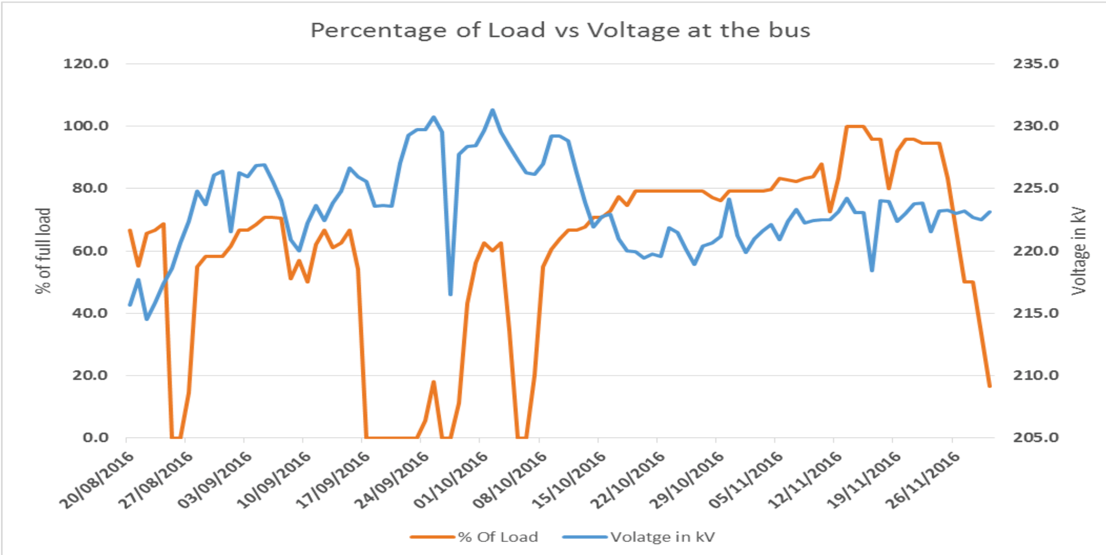

Fig 4: Percentage of load vs voltage plot of a Lift Irrigation project in SR

VI. SCHEDULING OF LIFT IRRIGATION LOADS

As on date LI loads operate as per the requirement of irrigation department without any schedule as a HT consumer. In order to exploit the flexibility available in the LI machines, these loads need to be despatched by a Load Despatch Centre (LDC). Most of these loads come under the jurisdiction of State Load Despatch Centre (SLDC). A robust scheduling, measurement and settlement mechanism should be in place. As on date a full-fledged ABT mechanism is in place only at Inter-State level. As highlighted in SAMAST [12] (Scheduling, Accounting, Metering and Settlement of Transactions in Electricity) report by Forum of Load Despatch Centers of India, the same needs to be implemented at Intra-State level also.

VII. SIMULATIONS AND RESULTS

Demand and generation profile of SR has been simulated for a high RE scenario for the period 1st Aug 2022 to 30th Nov 2022. SR as a whole, is considered as a single control area, with inter-regional links. Around 25% of the total projected LI loads are assumed to be available for flexibility. Optimization studies have been carried out considering the Lift Irrigation projects as a base load with 70% PLF in the base case without flexibility. The same case was re-run keeping the LI loads as flexible, with a constraint of having 70% PLF every day, assuming that will be the amount of water to be pumped as per the irrigation requirement. The LI load is distributed into 5 projects as given in Table 3. The optimization software used is PLEXOS from Energy Exemplar. Our studies projected a 7.2 BU of undespatchabe Solar energy & 4.6 BU of wind energy without flexible LI load. This power either has to be despatched to other regions or to be curtailed. The studies have been done again with a flexible LI load of 3120MW with varying Capacity Factor of 70%. The ramp up and ramp down of all the machines is considered as 2 MW/Min. This flexibility has resulted in reduction of undespatchable RE by 25% i.e from 5.4BU to 3.4BU.

Table 3: Details of LI loads assumed

LI load	Capacity of each machines (MW)	No of machines	Total Capacity (MW)
LI 1	40	9	360
LI 2	40	9	360
LI 3	40	11	440
LI 4	110	8	880
LI 5	120	9	1080
		Total	3120

VIII. Economics Of Operation

A) Revenue generation to the LI through providing ancillary services

LI projects are Government owned and are made with the goal of maximizing social welfare by irrigating dry lands. They don't have a direct return on investment. Grid support ancillary services provided by these LI projects will be an additional outcome and can improve the economics of operation. If the despatch schedule for a particular time block is more than base case (70% of installed capacity), then it is considered that Ancillary Down service was provided in that particular time block. If the despatch schedule is less than base case for any time block, then Ancillary Up service is considered to be provided. As this is a demand response from a LI loads, the terms Ancillary Up & Ancillary down are considered as reverse to that of a service provided by a generating station. Fig__ shows the ancillary despatch of 'LI load 1' from Aug'22 to Nov'22.

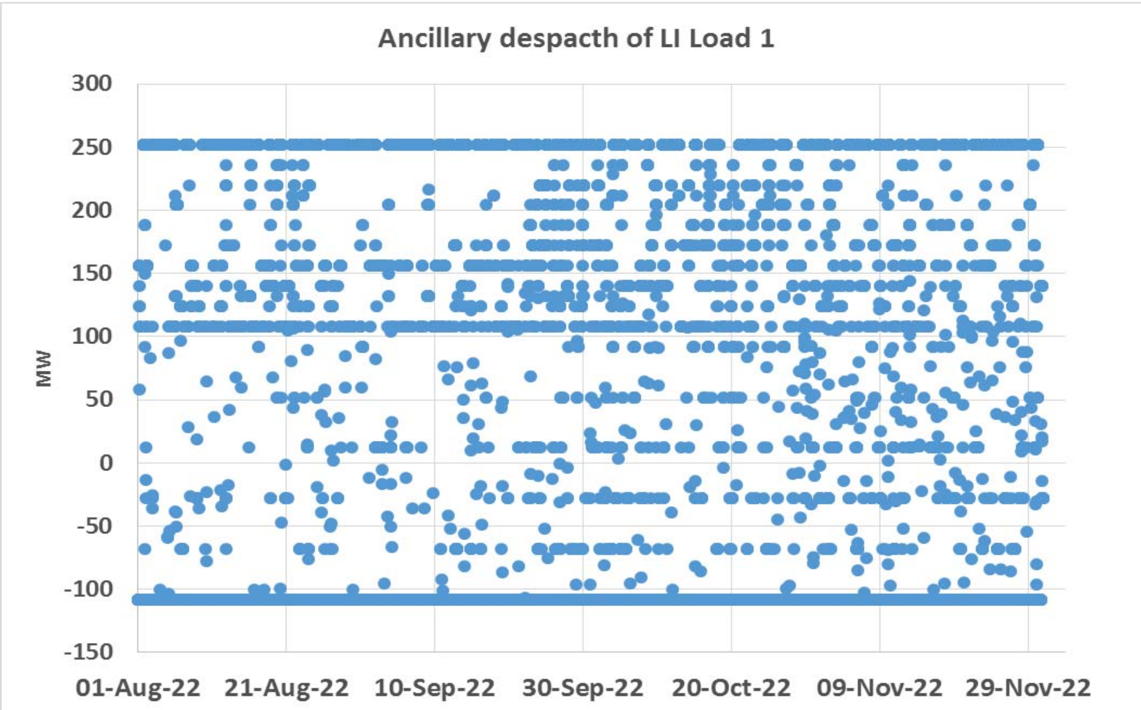

Fig 3: Ancillary despatch of LI load 1

Ancillary service is a privilege service provided to the system operator during exigencies. Being a privilege service, its price shall be more than market price. As on date, Ancillary services in India are being despatched under the head, Reserve Regulatory Ancillary Services (RRAS) and are applicable to thermal generating stations whose tariff is determined/adopted by CERC. A markup price of ₹ 0.50/kwh was determined by CERC. But in the near future a market mechanism needs to be evolved and prices of Ancillary Services are to be available for bid, similar to energy trading in power exchanges. Considering the above scenario, cost of ancillary service provided by the LI loads in 2022 is arrived using the average Market Clearing Price (MCP) in IEX between Aug and Nov from 2013 to 2017. The price is found to be ₹3.14/kwh. The markup price decided by CERC of ₹0.50/kwh was added to that to average MCP and cost of ancillary service from Aug to Nov 2022 is assumed to be ₹3.64/kwh. Total revenue the LI project owner may realize is given in Table 3.

Sita-Rama Lift Irrigation project phase-1 to be built in the state of Telangana is considered as an example. The power requirement for the project is 407MW, which is close to our assumption of 360MW for LI load 1 & LI load 2. The annual energy charges projected for the project is ₹ 430Cr[13]. From Table 3, 'LI 1' can earn a revenue of ₹ 140 i.e. ~30% of energy charges.

Table 3: Revenue for providing ancillary service

LI Load	Revenue in Cr
LI 1	₹ 140
LI 2	₹ 140
LI 3	₹ 167
LI 4	₹ 334
LI 5	₹ 409

B) Saving to home states in terms of relief in DSM charges

Often, states loose significant amount of money as DSM charges for their deviations from the schedules. These deviations tend to be high for renewable rich states. Fig 4 gives an indication of deviation by a renewable rich state in SR from Aug'17 to Nov'17. They have paid over ₹ 16Cr [14] DSM charges for overdrawing to the tune of 68MU. During the same period, the state had lost over ₹ 30cr [14] for under drawing around 31MU beyond the cap limits. These LI loads can provide very fast demand response and can be of great help in managing the deviations. The home state can avert such revenue loss, by optimally scheduling LI loads.

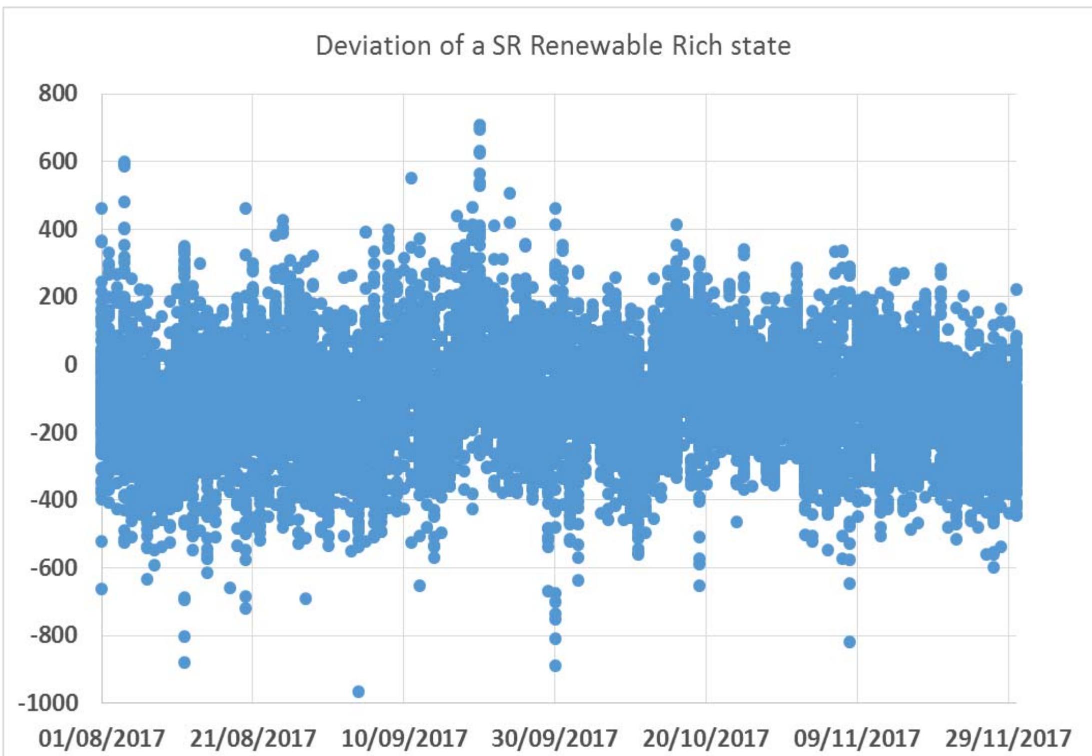

Fig 4: Ancillary despatch of LI load 1

IX. CONCLUSIONS

It can be inferred from the results that by effectively utilizing the flexibility available in Lift Irrigation loads, a better grid operation is possible with effectively reducing the instances of RE curtailments. Moreover, by employing Lift Irrigation loads under ancillary services, there could be significant revenue benefits to the Lift Irrigation project owner and the home state.

X. CHALLENGES AND WAY FORWARD

1. The process of scheduling and dispatch of LI loads needs to be done in co-ordination with the irrigation department.
2. To harness these intra-state loads, recommendations of SAMAST (Scheduling, Accounting, Metering and Settlement of Transactions in Electricity) at intra-state level is to be implemented.
3. Even though these machines are capable of high on & off duty cycles, the impact on the life and performance of the machines in the long run is to be studied.
4. Many of these projects are equipped with SCADA locally, which is to be extended to Load Despatch Center in order to have a centralized operation.
5. Frequency of duty cycle optimization can be studied for further improvement.
6. During the lean season, there is a possibility of Synchronous Condenser mode of operation of the synchronous motor for Reactive power support.

If the all the above technical constraints are addressed at design stage, better operation could be achieved.

XI. ACKNOWLEDGEMENTS

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XII. REFERENCES

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