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Design and Analysis of Uninterupted PowerGrid Using Hybridnation of Sustainable Energies

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Abstract— Numerous aspects must be measured earlier for implementing a Three-phase power generation system based on sustainable energy sources. Longstanding necessary data must be composed before creating any conclusions concerning the implementation of such a system. Potential of Solar, wind and hydel energy are precisely measured at Kadamparai location in TamilNadu, India. In this research, an effective analytical hybridization method is suggested for grid systems comprising exclusively of sustainable energy source like solar photovoltaic (PV), wind, and pumped hydro sources. One of the methods was tested numerically and analytically, the results can be applied to achieve emission free power grid. Hydro, wind, and solar photovoltaic energy are the deepest sustainable energy sources in worldwide installed capacity. However, no reports have been printed about hybrid grid systems encompassed of all three sources, simulation model and analysis are the first of its kind anywhere. This investigation may be pragmatic as a real-world guide for applying similar systems in various places. Wherever renewable sources are used in India, the main combination is about solar and wind only. This is the first novel analytical approach presents for connecting renewable energy sources to a utility grid.

Simulink analysis and mathematical modelling of renewable resources can extend year-round power supply to switchyard with use of underground water batteries. In future carbon emission percentage will be nullified and cure global warming and climate changes once implementing this project into real.

Keywords—hybrid, Solar photovoltaic, wind, pumped hydro storage, Kadamparai.

I .INTRODUCTION (*INDIA'S POTENTIALE IN RENEWABLE POWER AS ON 31ST MAY 2020*)

India announced a goal for 175 GW collective renewable powers installed capacity by the year 2022 inclusive of 100 GW solar and 75 GW wind. A capacity of 87.384GW has been set up by May 2020 constituting more than 23.58 percent of the total installed capacity includes 34.915GW solar and 37.756GW wind.[1] India has 4th and 5th global positions in the wind and solar power deployment respectively. Solar potential in India measured based on land availability and radiation was 748.98 GWp as on December 2019, includes potential of Tamil Nadu 17.67GWp [2].

National Institute of Wind Energy (NIWE) has installed over 800 wind-monitoring stations all over the country and delivered wind potential maps at 50 m, 80 m, 100 m and 120 m above ground level. The latest assessment indicates gross wind power potential of 302.25 GW and 695.50 GW in the country at 100 metre and 120 metre respectively; above ground level [3]. TamilNadu have wind potential of 33.8 GW and 68.75GW for the height above ground level 100 m and 120 m, respectively. Also, total hydropower installed capacity and small hydropower capacity are 45699.22MW and 4683.16 MW respectively.

Totally 7600 km coastline surrounded by seawater on three sides has tremendous power generation potential from offshore wind energy**.** Initial assessment made on offshore wind energy potential within the identified regions has been projected to be about 70 GW off the coast of Gujarat and Tamil Nadu only.

Total installed capacity of renewable energy in India and TamilNadu shown in Fig.1. & Fig.2. The Ministry of New and Renewable Energy (MNRE) is assigned task for developing hydro power projects of capacity up to 25MW, categorized as Small Hydro Power (SHP) projects to meet power requirements of remote and isolated areas in a decentralized manner. Small hydro Power projects are further categorized into small, mini and micro hydel projects based on their capacity as follows: (1) Micro hydel ≤ 0.1 MW, (2) Mini hydel > 0.10 MW to ≤ 2.00 MW and (3) Small Hydel > 2.00 MW to ≤ 25.00 MW [4]. Nation issued Wind-Solar Hybrid Policy on May 2018 to provide a framework for implement of large grid connected wind-solar PV hybrid system for optimal and effective utilization of wind and solar resources, transmission infrastructure and land. Hybrid systems will help in reducing the intermittency

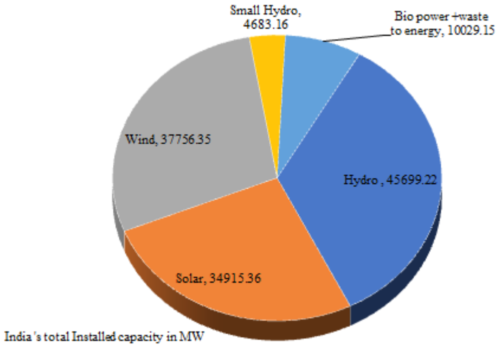

Fig. 1. India total installed capacity of renewable energy

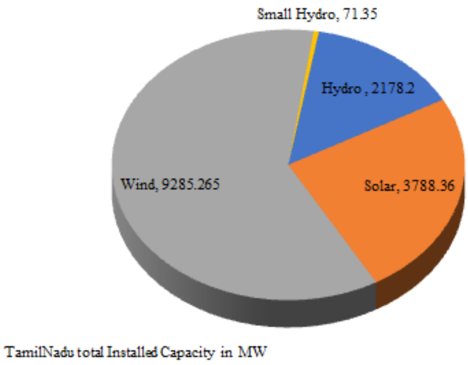

Fig. 2. Tamilnadu total installed capacity of renewable energy

in renewable power generation, achieving better grid stability and encourage new technologies, way outs involving combined operation of wind and solar PV plants [4]. India has greater potential of wind and solar PV hybrid can integrate with grid [5]. Hydro, wind, and solar PV hybrid connected off-grid system electrifying villages in India neighboring country with uses of grid tied inverter and battery charger [6]. Optimized operation of solar PV with pumped hydro storage proposed model with IEEE RTS -96 and MATLAB simulation checked adaptability and feasibility of system for large scale PV integration [7]. Dynamic risk setup between shaft vibration and governing strategy has been identified and unified model for hydraulic turbine and governing system developed and analyzed with Simulink model [8]. Peak power demand increases the necessity of energy storage, pumped storage scheme is the best to the world for its unique operational flexibility also problem in Indian pumped storage scheme is insufficient power for pumping water lower reservoir to upper reservoir during off peak period. Poor of lower tail pool also major problem to be rectified to develop the irrigation [9]. Best possible hybrid system for the massive energy storage completed with pumped storage only. Efficiency of energy storage is greater than 87 percentages [10]. Response surface optimization was successfully applied in the hydraulic design of pump-turbine runners to improve pump hydraulic efficiency by 1.06% at its best. 78 percentage of round tip efficiency of pump turbine increase the efficiency of storage [11]. kadamparai region is surrounded with eight hydroelectric water generating circle in TamilNadu [12]. This research paper analyses the novel model of the Pumped Hydro Storage integrated to wind and Solar PV for the higher sustainable energy potential location in TamilNadu. This paper structured the hybrid model to solve the existing issues raised in pumped storage addressed by State Load Despatch Centre (SLDC) TamilNadu.

II. Land Survey for Project

Kadamparai hydroelectric pumped storage plant is in Anamalai hills in Coimbatore district of Tamil Nadu in Southern Region (SR) India with 10.3896-degree north latitude, 77.0435degree east longitude, commissioned in 1986. Upper reservoir of the plant is Kadamparai dam and Lower reservoir of the plant is lower Aliyar dam. The powerhouse is mounted in underground 200 metre below the ground level with 4 numbers of reversible Francis Turbine units each having a generating capacity 100 MW. Kadamparai Power House (KadaPH) (capacity 4x100 MW), the water for power generation is taken from Kadamparai Dam and delivered to Upper Aliyar Dam.is shown in Fig.4.During non-peak hour, the water in Upper Aliyar Dam is pumped to Kadamparai dam by pumping operation. Each unit distributor commonly placed at 710 m elevation. Water potential, minimum requirement of water per unit power generation and turbine operating parameters are listed at KadaPH in Table 1. Table 2. & 3, respectively.

TABLE 1. WATER POTENTIAL AT KadaPH

Location	**Height of Dam (Feet)**	**Full Reservoir Level (FRL) (Feet)**	**Storage in Million Cubic feet (MCft.)**	**Minimum Draw Down Level (Feet)**	**Dead Storage (Feet)**
KadamParai Dam	221.45	3770	1089	3648	140.57
Upper Aliyar Dam	265	2525	937.89	2445	209

TABLE 2. GENERATION CAPACITY OF ONE UNIT

Power Generation Details	**Generation in Million Unit**	**Water discharge in Cubic meter. load**
Per Unit /Hour Generation @full (100 MW)	0.1	104772.33
All the four Units run between18.00 Hrs. to 22.00 Hrs. (i.e. 04 Hours)	1.6	1676357.32
Equivalent water Pumped Details	*Consumption in Million Unit*	*Water Stored*
Per Unit/ hour consumption and water stored	0.11	84950.54
If four Units are run as PUMP mode the time required for the above discharge (59.2 MCft.) Pump Running Hours 05 Hrs.	2.2	1676357.32

Grid was operated at lower frequency i.e. between 48.5Hz & 49.0Hz for more times till 2002 and less. Surplus power was available during off peak time Surplus power was also available in the grid during National holidays, and on Sundays by which time two or three units were utilized as pump at Kadamparai. KadaPH turbine - pump operation and its time response are shown in Fig. 4. & Table 4. respectively.

TABLE 3. TURBINE OPERATING PARAMETER

Make of Generator / Turbine	**UNIT 1 GEC BOVING UNITED KINGDOM**
	UNIT 2,3&4 BHEL INDIA
Type of Turbine	Francis Reaction Reversible
HEAD for each Powerhouse	1) 395 m (GENERATOR MODE)
a) Maximum	2) 413 m (PUMP MODE)
b) Minimum	1) 323 m (GENERATOR MODE)
	2) 341 m (PUMP MODE)
speed of Machine	500 rpm

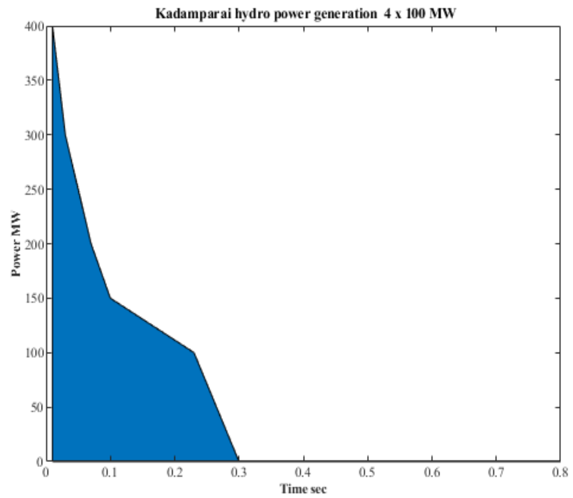

Fig. 4. Time response and power generating mode

A. Performance Chart for the KadaPH station

Fig.5 indicating the monthly plant capacity factor of Pumping mode for the year of 2017 -2020 is being 28 percentages. Fig.6 shows the worst cases of plant operation during monsoon depletion. Green color states the generation also violate states the pumping mode operation necessary MU (Million Unit). Red and yellow shows the Designed basic MU required for generation and pumping respectively.

The motor input required is about 110 MW. If all the four units are operated as pump, then the power input required at station end is about 440 MW. MU required for the year 2011 to 2018 is listed below.

2010-11 -- 612 MU

2011-12 -- 532 MU

2012-13 -- 335 MU

2013-14 -- 493 MU

2014-15 -- 511 MU

2015-16 -- 414 MU

2016-17 -- 330 MU

2017-18 -- 9 MU only due to water scarcity

During 2017 to2018 monsoon depleted the MU required for the pumping mode. This worst situation was addressed by SLDC minutes of meeting report. Though, wind capacity is higher at that period pumping not done due to water level reaches below the silt level.

B. Major Problem Identified to be Solved

- Low voltage problem in KadaPH
- Due to low voltage, stator of the motor draws more current which may cause damage to the windings.
- Interconnected Transformer (ICT) Tap Change was facilitated by Southern Region Load Despatch Centre (SRLDC) at Udumalpet Sub Station (SS) to maintain the voltages at Kadamparai SS.

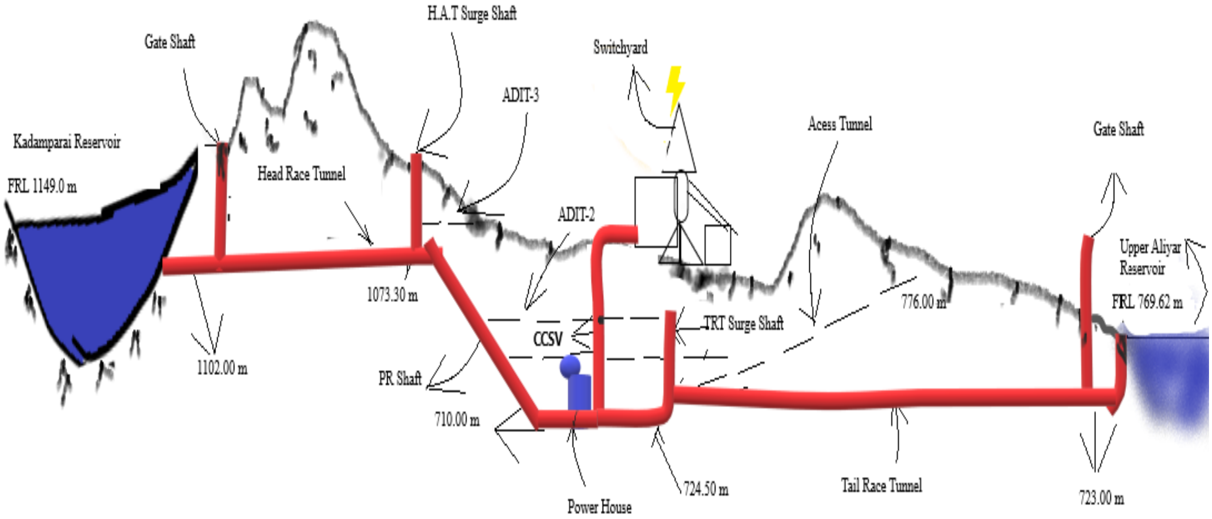

Fig.3. Kadamparai pumped storage viewpoint

TABLE 4. GENERATION AND PUMP MODE TIME

Mode	Condition	Response Time
Generator	Stand still to on-line	5 min
Generator	On-line to full load	Few seconds
Motor	Stand still to Synchronous condenser	9 min
Motor	Synchronous condenser to Pump	1 min

- Reactive power shortage at 230 kV and below of Kadamparai substation.
- Finally Lack of water availability due to the monsoon.

C. Wind and Solar Potential at KadaPH

Fig.7. shows annual wind energy production is 67774 kilowatt-hour per Megawatt installed capacity (kWh/per MW), annual solar energy production per MW is 1430690 kWh and annual hybrid energy production 4298464 kWh, those values used for Simulink analysis.

Southern regional hydro is highly monsoon dependent, during summer due to depletion of reservoir level reducing power generation. Some day’s utilization factor has reached as high as 72 percentages. Annual average utilization factor is 38 percentages.

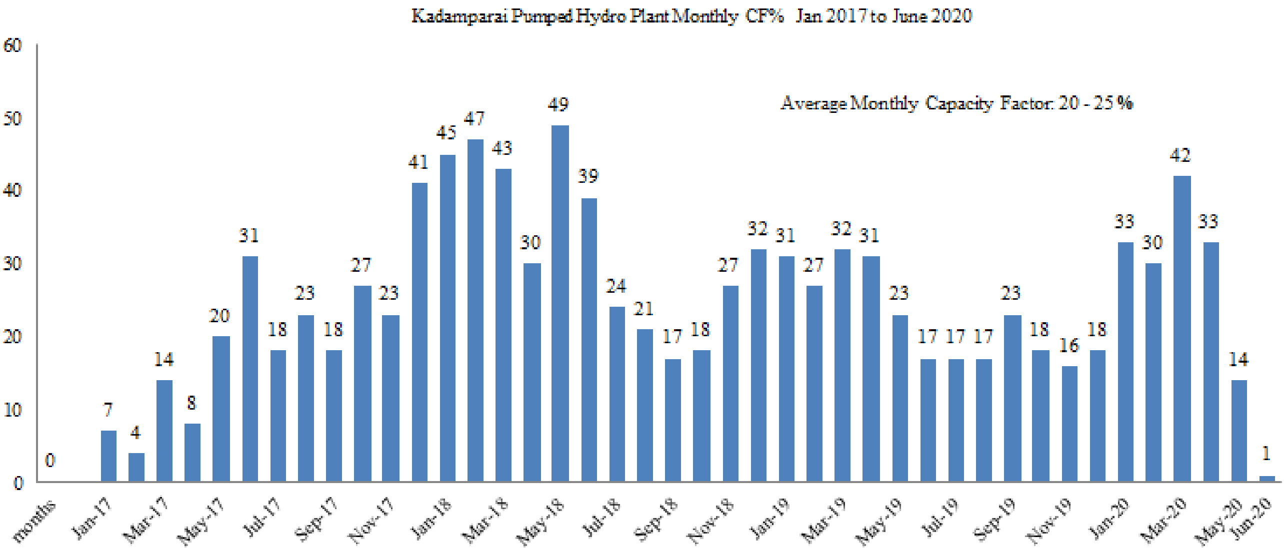

Fig.5 KadaPH monthly capacity factor percentage from Jan2017-20

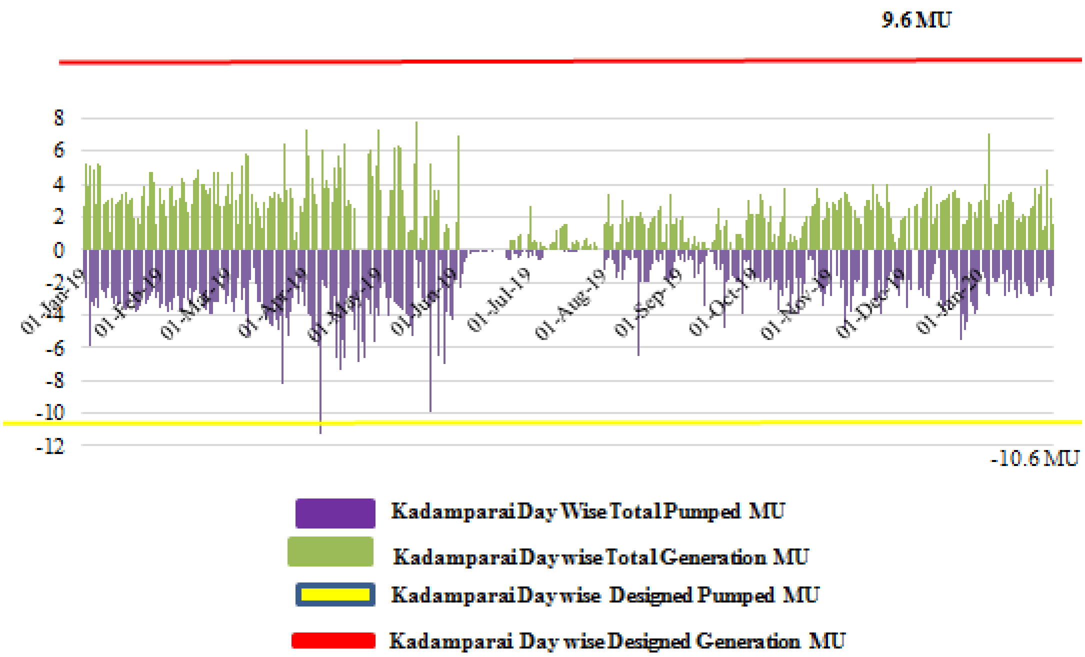

Fig.6. KadaPH daily operation load cycle with designed value n MU from Jan-2019 to Jan-2020

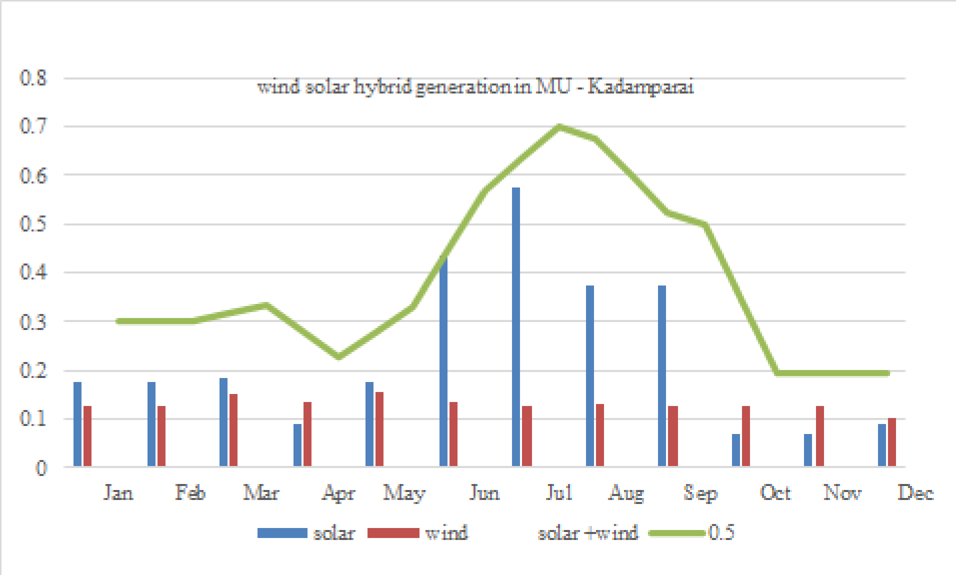

Fig.7. Wind & solar potential at KadaPH. -Test done with 1MW solar and 1MW wind power at 100 m agl.

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III. HYBRID MODELING AND SIMULINK ANAYSIS.

The Simulink parameters, value obtained from data acquisition system for solar, wind and pumped hydro storage plant are given as inputs for simulation. For the pumped hydro storage values are tabulated as per variable speed operation of reversible pump-turbines in Fig.8 and Fig.9. Various heads of 341m, 381m, and 413 are assigned for Simulink to achieve 80MW, 90MW, 100MW and 110 MW pumping mode [13]. Nominal power of solar, wind and hydro used various with various speed pump mode to find the optimal solution.

IV. Conclusion

24*60*60 seconds simulation done by Simulink analysis. The result plots in Fig.11, indicates that when solar and wind reaches the Grid range turbine is shutting down at 5 hrs. Once peak demand reached during solar low wind and hydro combinations has been setup to make up the Grid. Whenever the combinations reach maximum pump mode will be operated. Kadamparai excitation frequency adjusted by voltage source converter located between grid and generator.

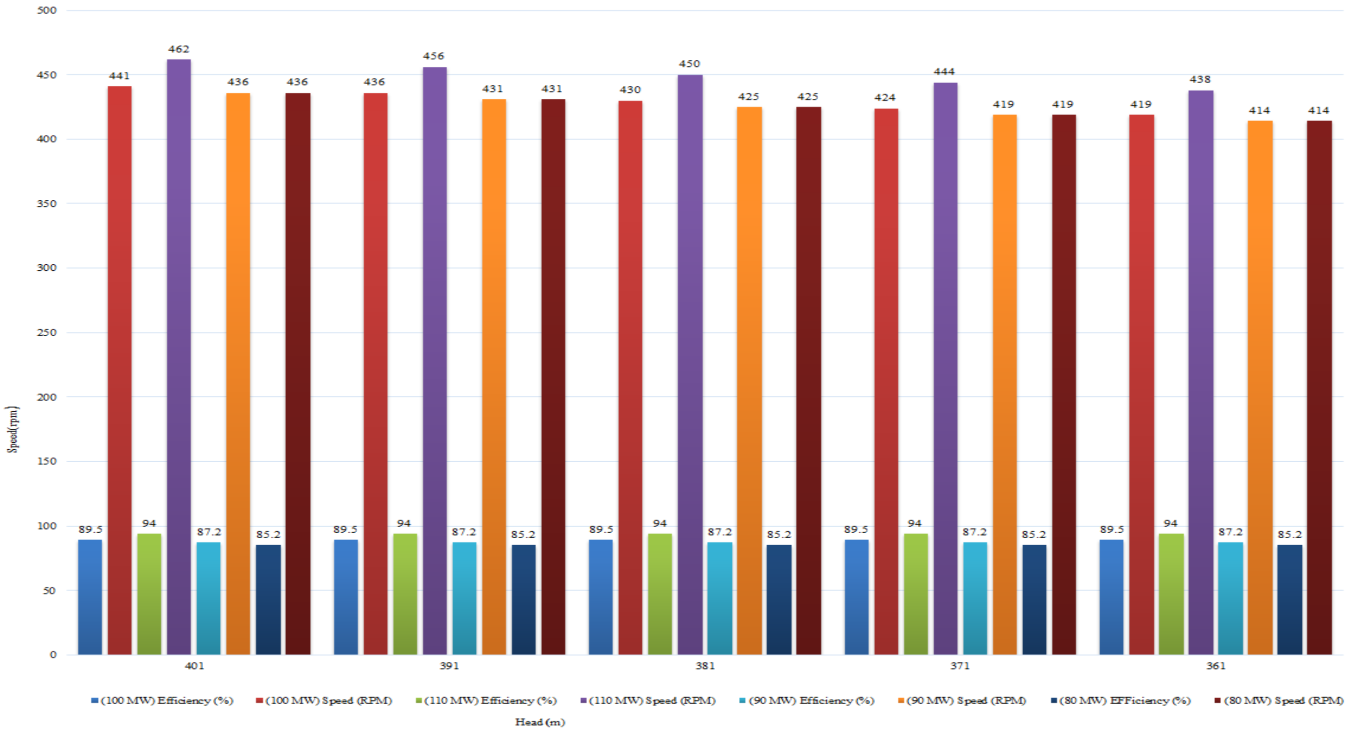

Fig.8. Wind & solar potential at KadaPH. -Test done with 1MW solar and 1MW wind power at 100 m agl.

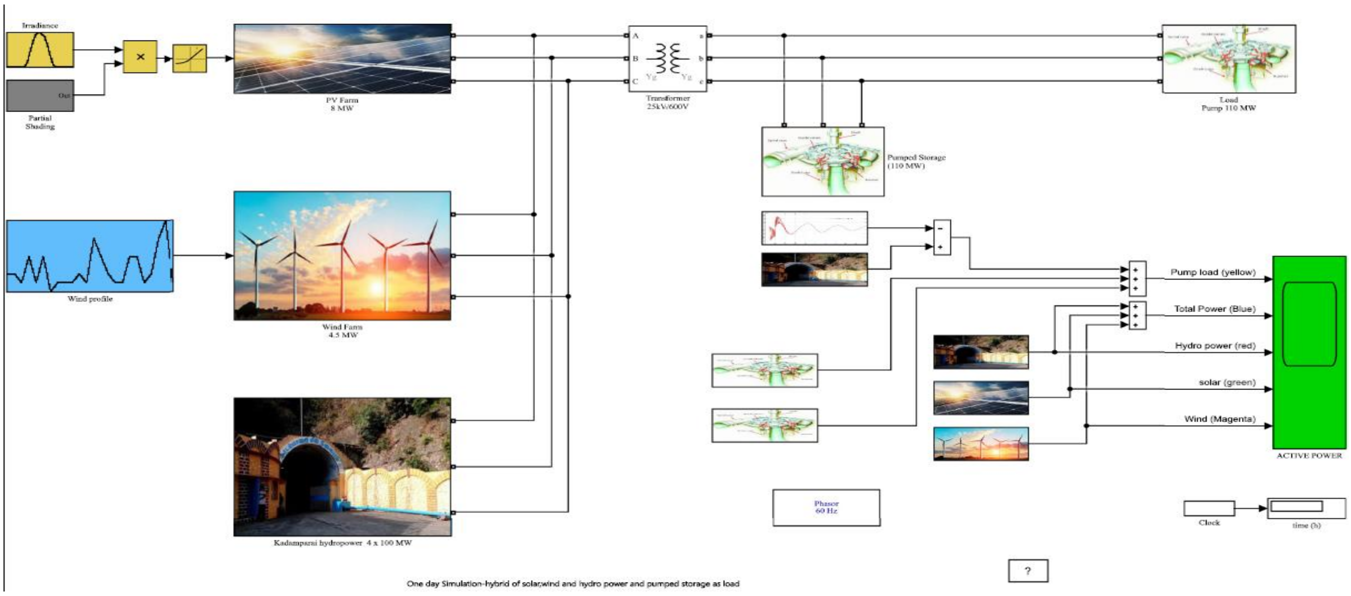

Fig.9. One day simulation of Hybrid model with Solar, Wind and Pumped hydro storage.

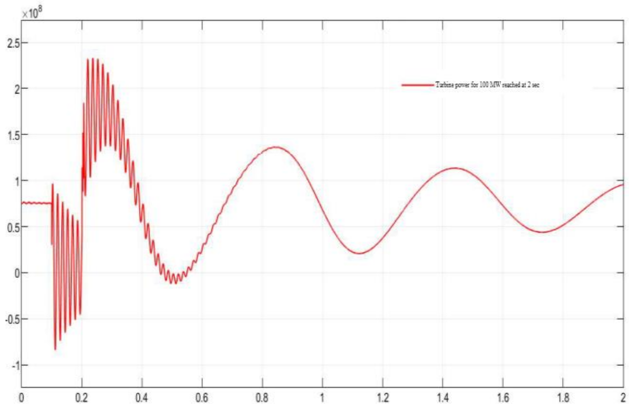

Fig.10. 100 MW turbines simulation for 2 sec

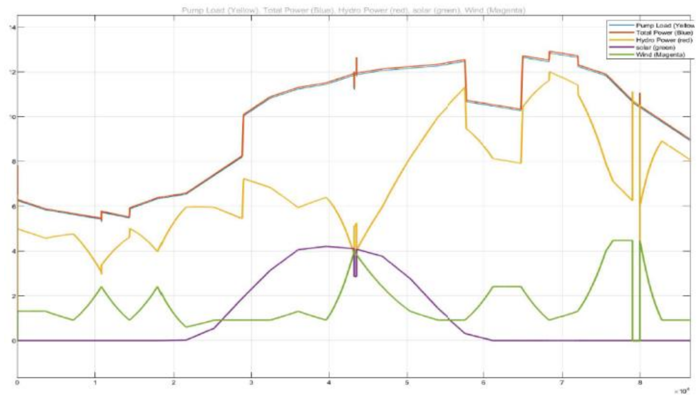

Fig.11. One day simulation result of Hybrid model with Solar, Wind and Pumped hydro storage

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