# Flexibility Management in Renewable Energy Source Operated Power Systems using Decision Support System

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**Abstract :** In the recent days, energy mix performed by using the Renewable Energy Sources (RES) is gaining wide popularity. The control of predictability and generation takes a progressive loss as RES is penetrating increasingly in the energy mixes due to the non dispatchable nature of the energy produced from these sources. For ensuring and maintaining stable operation, the power system flexibility is increased when higher penetration levels are attained by RES. A Decision Support System (DSS) is used for energy conversion and storage systems which can be managed by an Information and Communication Technology (ICT) tool. The H2020 PLAnning and operational tools are used for optimizing energy flows and synergies between energy NETworks (PLANET) along with DSS for controlling the technology wherein power is converted into either heat or gas (P2X) by evaluation, management and dispatch. Further analysis is done in terms of energy evaluation and economic benefits with respect to P2X technology and its flexibility.

**Keywords:** Decision Support System; Energy Conversion; Flexibility; Sustainability; Renewable Energy Integration;

## 1. Introduction

The emission of anthropogenic greenhouse gases has increased tremendously leading to the rise in global temperature by $0.8^{\circ}\text{C}$ since the early twentieth century. Various measures have been taken so as to moderate this hazardous trend. Several objectives and guidelines are provided by the European Union (EU) for this purpose. Over 30% of emission globally is caused by the power sector alone, making RES the key player in this regard in the near future [1]. The generation and consumption of power has to balanced, which is a major challenge as the contribution of RES in energy mix rises, while the intrinsic nature of these sources produce energy that is not in a dispatchable form.

In the existing infrastructural scenario, facilitating the integration of RES as well as handling the random variations in production of energy is to be handled to offer the energy dispatch module with an improved degree of freedom for obtaining better penetration of RES. A wide range of solutions and technologies like the energy storage using Virtual Energy Storage (VES) [2], Power-to-Gas (P2G) based energy conversion [3] and so on are required for attaining proper grid operation. This enables increased interconnections and improved flexibility in the energy sector. Analysis of the internal flexibility potential in energy systems is essential for predicting the energy flow and defining appropriate measurement systems as more customer centric energy systems are developed.
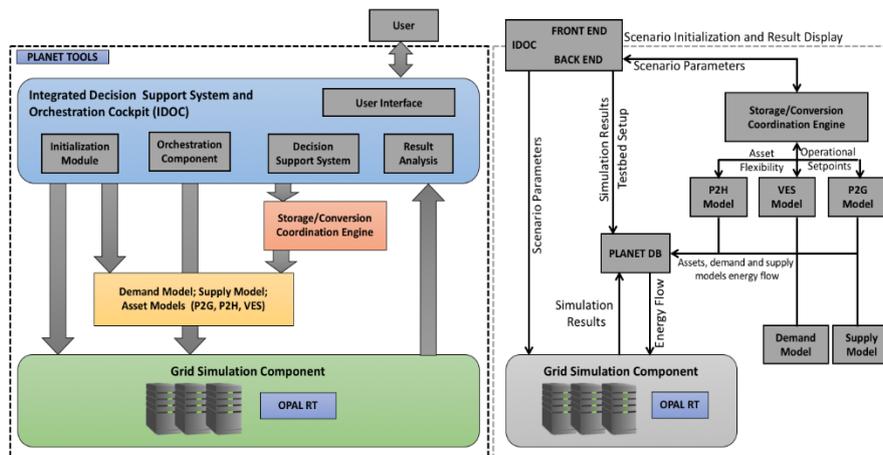
Figure 1: PLANTE tool Architecture

The grid simulation component, Storage/Conversion Coordination Engine (SCCE) module [4] of district level making the optimization module, Asset (VES, P2H, P2G) module, supply and energy demand module and Integrated Decision Support System and Orchestration Cockpit (IDOC) module are the major functional components that contribute towards the orchestration module and user interface of the PLANET DSS [5]. Identification of various ICT modules and their relationship with reach other is represented in figure 1 depicting the Architecture of PLANET tool at a high-level range. IODC [6] can be used for communication and acts as an interface between the user and the PLANET tool as represented in Figure 1.

This can be accessed through a web-based User Interface (UI). With the help of UI, definition of grid-connected asset parameters, demand/supply modules and networks can be done for initializing the energy scenario and visualization of results through simulation. The PLANET Database (DB) is used for storage of the energy scenario. Further, the IDOC back-end is used for dispatching the initialization parameters to the corresponding modules. A certain degree of flexibility can be offered to the system by each asset based on the operating condition at every step during simulation as well as the operating parameters. For this purpose, python script is developed using the SCCE for calculation of the optimal operational sett-points for VES, P2H and P2G assets based on the grid requirements and the available flexibility.

The reverse power flow is to be reduced by optimization of the network energy flow through optimization algorithm. The energy floe of all the modules involved is analysed using the eMEGAsim Power Grid simulator of OPAL-RT along with the grid simulator component by solving the power flow calculation. The simulation results can be visualized using the IDOC back-end and PLANET DB. Detailed simulation of the power grid behaviour can be performed using the OPAL-RT [7] simulator. MATLAB/Simulink environment is used for developing the asset models [8]. The energy generation

and consumption as well as the optimum working set points of the modules are received by the flexible asset through the SCCE controller.

## 2. Architectural Flexibility of PLANET

Several user interfaces making the front end components and other back end components are the major constituents of PLANET DSS. Stimulation scenario set up, scenario transfer and utilization of central simulator for execution of simulation as well as result visualization are the major functionalities of this system. Further, result comparison using the simulation results of previous execution and so on are additional functionalities available in this system. Figure 2 depicts the steps involved in utilization of PLANET DSS UI. A new energy scenario is created by the user on registration by means of parameters relating to economy, technology, grids, horizon and location. Further, at the next level the simulation scenario is started and the results are visualized in terms of utilization of direct energy sources for electricity demand fulfilment and so on [9]. Comparison of the previous scenario with the obtained results is the next level where two diverse scenarios can be compared based on the withdrawn electric power from external electricity network.
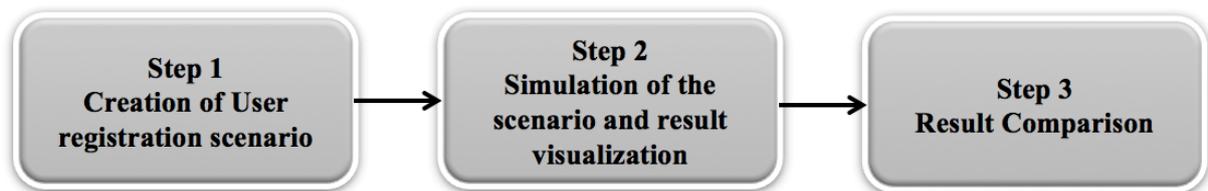


Figure 2: Utilization Steps involved in PLANET DSS

Ancillary services are offered to the grid based on the ability of a system for modifying the generation or consumption profile of energy which is cumulatively termed as flexibility of the system. Flexibility can be defined in terms of positive and negative form. Ability of the system to reduce the production of energy and simultaneously improve the consumption of energy is termed as positive flexibility. Based on the need for maintaining the stability of the grid, the energy in the network should be balanced if there is an increase in the RES generation [10] when compared to the total load. This leads to the requirement of positive flexibility. Increasing the total production of energy or decrease in the total consumption of energy is caused by negative flexibility to a certain extent. This is used at critical peak pricing events where the production of RES is less compared to the total load.

### 3. Development of Use Case Scenario

The flexibility of a P2G system is exploited for improvement of the energy performance by simulating an energy scenario using the primary functioning prototype of the PLANET tool for demonstrating the potential of the current. Issues in the electric grid may be imposed by high penetration of renewable sources that can be characterised by a future scenario in comparison with the analysed scenario. Schematization of the possible energy flow factors is also performed. A series eight node medium voltage network feeder is also analysed. Table 1 provides the analysis in terms of P2G assets, CHP plant, PV plant and Uncontrollable loads in connection with the electric grids [11].

The Power Node equation of the proposed approach can be given by

$$C\ SoC = \alpha_{load}\beta_{load} - \alpha_{gen}^{-1}\beta_{gen} - \gamma + \delta - \nu$$

where C represents the capacity of internal storage of the power node, the normalized State of Change is given by SoC, the power consumption of the model is given by $\beta_{load}$ and the efficiency of conversion or charging is given by $\alpha_{load}$. $\beta_{gen}$ provides the generated electricity of the device and $\alpha_{gen}$ provides its corresponding efficiency. The flow of energy through the system is given by $\gamma$. The energy loss enforced in the system is provided by $\delta$ and the loss occurred in energy storage is represented by $\upsilon$. This equation can further be expanded for demonstrating the primary operational prototype of PLANET and its current potential based on the analysis scenario. The constraints over the electricity generator or load are as follows

Maximum Load or Power generation: $0 \leq \beta_{load}^{min} \leq \beta_{load} \leq \beta_{load}^{max}$

Minimum Load or Power generation: $0 \leq \beta_{gen}^{min} \leq \beta_{gen} \leq \beta_{gen}^{max}$

The restrictions due to the ramp rate capacity of the device are given by $\beta_{load}^{min} \leq \beta_{load} \leq \beta_{load}^{max}$ and $\beta_{gen}^{min} \leq \beta_{gen} \leq \beta_{gen}^{max}$.

Table 1: Electric Grid and its associated Technologies

| Grid Node | Electric Peak Load [MW] | PV Nominal Power [MW] | CHP-Nominal Power [MW] | P2G-Nominal Power [MW] |
|---|---|---|---|---|
| 1 | 0.2 | 1.5 | - | - |
| 2 | 0.3 | 2.0 | - | 1.5 |
| 3 | 0.5 | - | - | - |
| 4 | 0.4 | 1.5 | 0.4 | - |
| 5 | 0.5 | 2.0 | - | - |
| 6 | 0.3 | 1.5 | - | - |
| 7 | 0.2 | 1.5 | - | - |
| 8 | 0.6 | - | 0.2 | - |
| 9 | 0.6 | 1.5 | 0.3 | - |
| 10 | 0.7 | 1.0 | 0.3 | - |
| SUM | 4.3 | 12.5 | 1.2 | 1.5 |

For reducing the reverse power flow and absorbing the overproduction of renewables, SCCE control is used for optimization of P2G operation in this study [12]. When compared to the instantaneous demand in energy, increase in the uncontrolled production of renewables leading to overproduction of energy may occur in high RES penetration cases in distributed energy generation scenarios. In such cases, the transmission network absorbs the over-production of energy. This can be represented by utilization of renewables in a non-optimal manner. In such scenario, the distribution system does not get the adequate protection required. This is due to the inability of the distribution grid to handle the reverse power flow because of the poor implementation of protection scheme. Violation of current and voltage limits are restricted by the reverse power flow.

The flexibility of input as scenario assets similar to P2G plant flexibility as well as the individual nodes generation and consumption is obtained by the SCCE [13]. For every node in the network, the generation and consumption of energy is minimized using a control algorithm. This leads to indirect optimization of reverse power flow. Insufficient flexibility in certain nodes leads to unbalanced nodes in which the generation and production cannot be balanced. In such cases, the flexibility of the assets installed in the nodes nearest to the unbalanced nodes are exploited by SCCE. Parameters like P2G lifetime, P2G OPEX, P2G CAPEX, CHP thermal efficiency, CHP electrical efficiency, Methanation efficiency, Electrolysis efficiency, G2H nominal power, DH heat peak power, time step, location and time horizon are essential for the simulation scenario [14].

## 4. Results and Discussion

Utilization of the flexibility of a P2G plant by means of PLANET tool in RES with high penetration is analysed. Two scenarios are considered for this purpose- one with a P2G plant installed and another without any assets for energy conversion. Figure 3 represents the assessment of electricity production scenario without any assets for conversion of energy over a duration of 4 days. The profile

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of electric load is also analysed for the grid branches. The photovoltaic energy satisfies the load in the scenario that is considered. For this purpose, it utilises the high voltage network energy and the energy generated by the CHP plants which contribute to a total of about 47% of the annual energy. The excess energy generated from the grid need not be absorbed at a particular point where P2G is turned off by the SCCE.
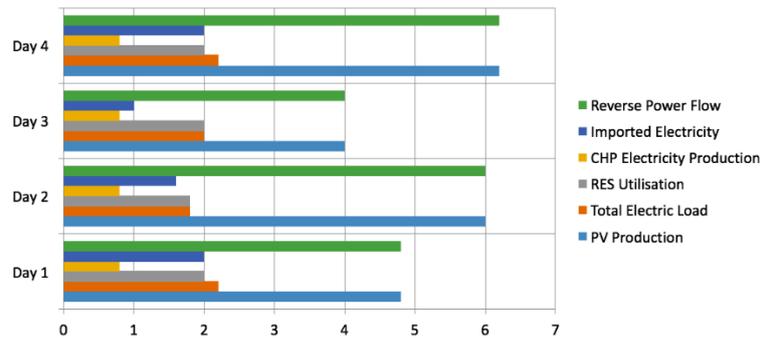


Figure 3: Assessment of Energy production without any assets of conversion

Overproduction of energy which is not consumed occurs due to the huge number of installed PV power. This leads to a yearly contribution of over two thousand hours and 40% of reverse power flow. Figure 4 represents a similar scenario of energy flow. In this case, a P2G is installed for reducing the reverse power flow. Increasing the electric load during overproduction of RES is made possible by means of a flexible unit thereby improving the utilization of renewable energy. An SCCE controller regulates the P2G load at every step based on the flexibility values. This process continues till the negative flexibility reaches zero and further reduction in consumption of energy is not possible. At point 4, P2G operates at its nominal power. At this point, maximum value is reached by the negative flexibility and simultaneously, the plant works at a nominal capacity with the positive P2G flexibility at zero.
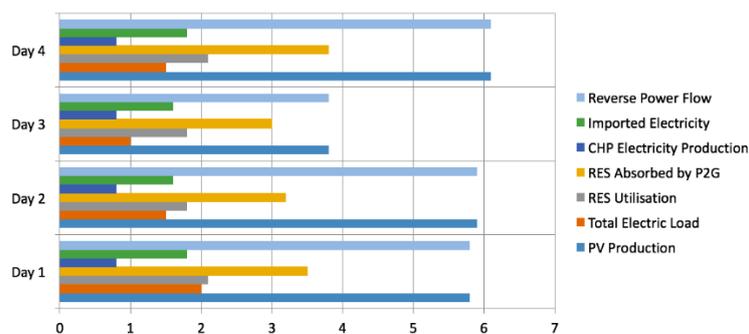


Figure 4 Assessment of Energy production with P2G

Energy consumption is also analysed using PLANET from an economic view point. Based on the analysis, it can be concluded that utilization of this technique can contribute towards great reduction in the reverse power flow by a factor of over 60% in terms of power and 40$ in terms of time. P2G flexibility and its application has a significant impact on the given scenario however, it imposes high cost trade-off for the reverse power flow reduction. Hence it is essential to balance the economy of the plant for practical implementation of the same. The visualization of results of the simulation scenario of the central simulator is discussed in detail in this section.

## 4. Conclusion

It is essential to provide an optimized solution in terms of environment as well as economy for analysis of the emerging complex energy systems. This is essential due to the non dispatchable nature and increase in the distributed generation of renewable energy sources. An ICT DSS tool has been developed by the PLANET project for policy makers, P2X plant managers and grid operators. This tool aids in the P2X energy conversion technologies for analysis and optimization of flexibility. The district scale system of energy analysis can be performed using this tool. Selection of technologies associated to the network, the network loads and their corresponding sizes has to be done for analysis of the scenario through the web UI.

RES and meteorological generation data and corresponding to the initialized simulation and user's choice are identified for choosing the geographical location of the user. This paper performs a detailed analysis of the technologies involved and their flexibility on implementation of the PLANET DSS tool.  Available flexibility is evaluated using a mathematical model. Power Node approach is used for calculation of flexibility. This technique is highly efficient and can be implemented in almost all technologies associated with the load assets or generation based electrical network. The potential of the tool used is analysed in terms of dispatching and management of flexibility in terms of high penetration RES. It is found that issues related to grid balancing occurs due to large overproduction of energy with renewable penetration of about 50%. Balancing the economy of the plant is essential as the technology is quite expensive when compared to the number of full load hours.

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