LARGE-SCALE INTEGRATION OF VARIABLE RENEWABLE ENERGY IN ELECTRICITY SYSTEMS

Issues, analysis and recommendations

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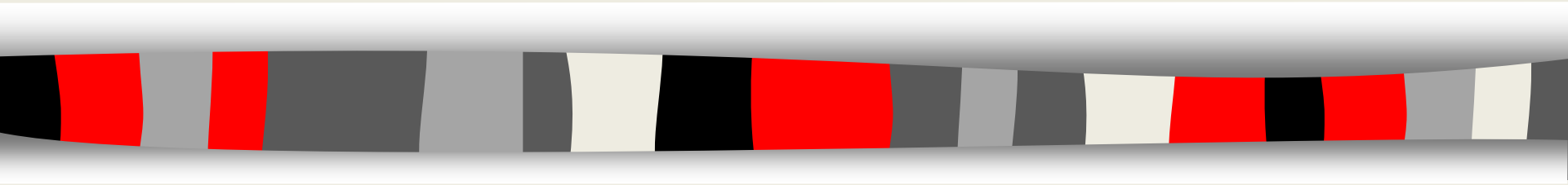
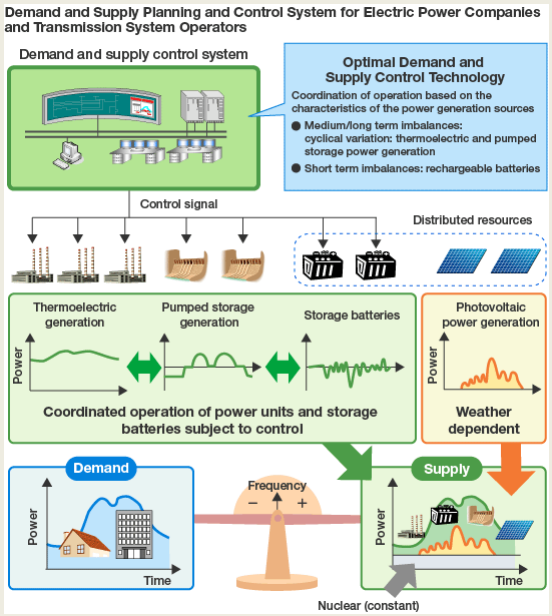


Introduction



- Changes and challenges in power system operation and planning seen in the last 2 decades driven by:
  - Deregulation of electricity markets;
  - Rapid integration of RETS such wind and solar;
  - Increasing role of a balancing market; and
  - Power system interconnection

Introduction

- To encourage large-scale integration of variable renewable energy resources (VRE) requires removing existing and future barriers

Integration Issues

- **Solar and Wind → becoming important and significant electricity generation mix around world**

- **Increased deployment of VRE**
  - Requires increased operating reserve to balance the system and manage system frequency.
  - Increases the overall cost of operating the power system.

Integration Issues

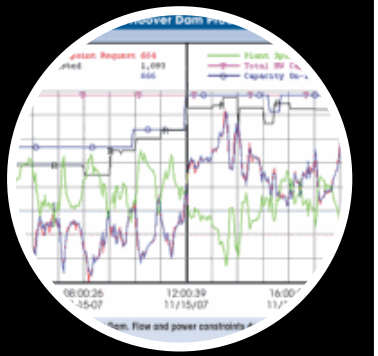
- **Uncompetitive electricity markets to attract integration of VRE due to:**
  - Inadequate cross border transmission links;
  - Existence of dominant vertically integrated power companies.
  - Biased grid operators
  - Low liquidity in wholesale electricity markets
- **Other integrations issues →**
  - Inadequate polices on third party access to grids at fair tariffs;
  - Inadequate grid codes

Integration Issues

High costs to reinforce transmission network

Need for VRE to provide grid support (capacity credit issues)

Operation of an interconnected system

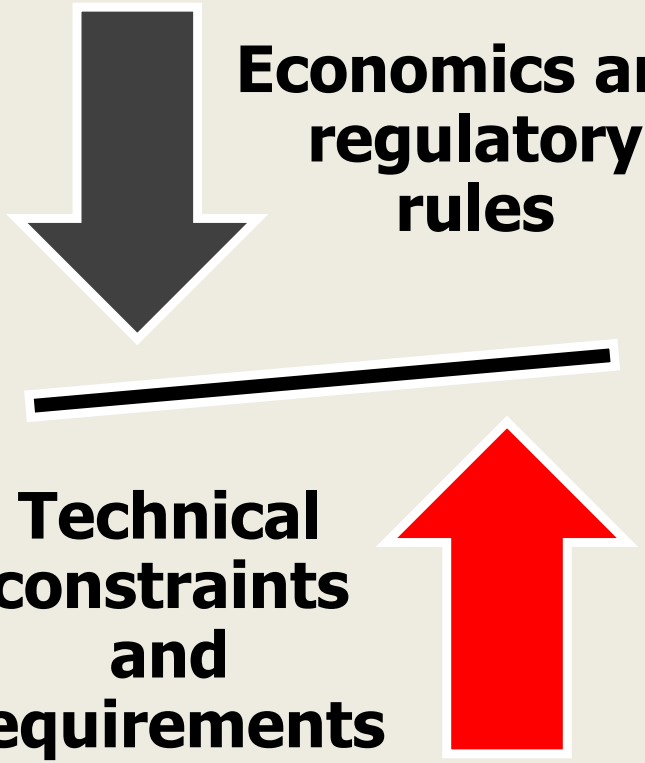


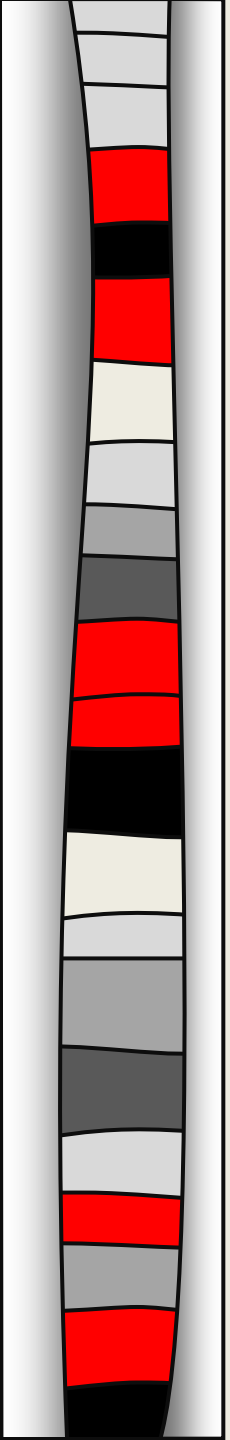
Forecasting errors and associated cost

System Operator's point of view

Analysis

- What factors determine the capacity of most power systems to absorb significant amount of VRE?





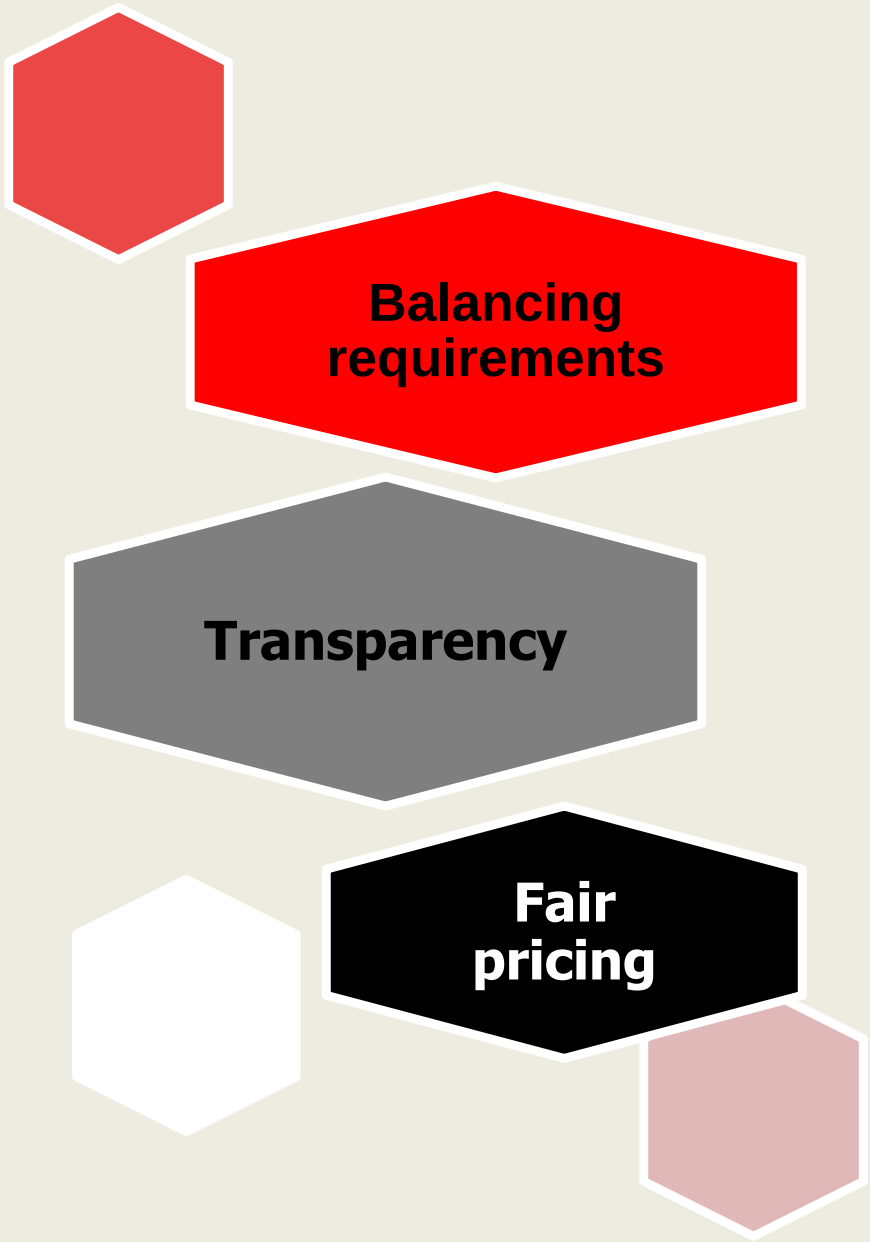
Analysis

Integration issues that require immediate redress

- Market dominance
- ineffective competition policies
- removal of discriminatory practices
- inadequate grid codes
- inadequate policies concerning third party access to grids at fair tariffs

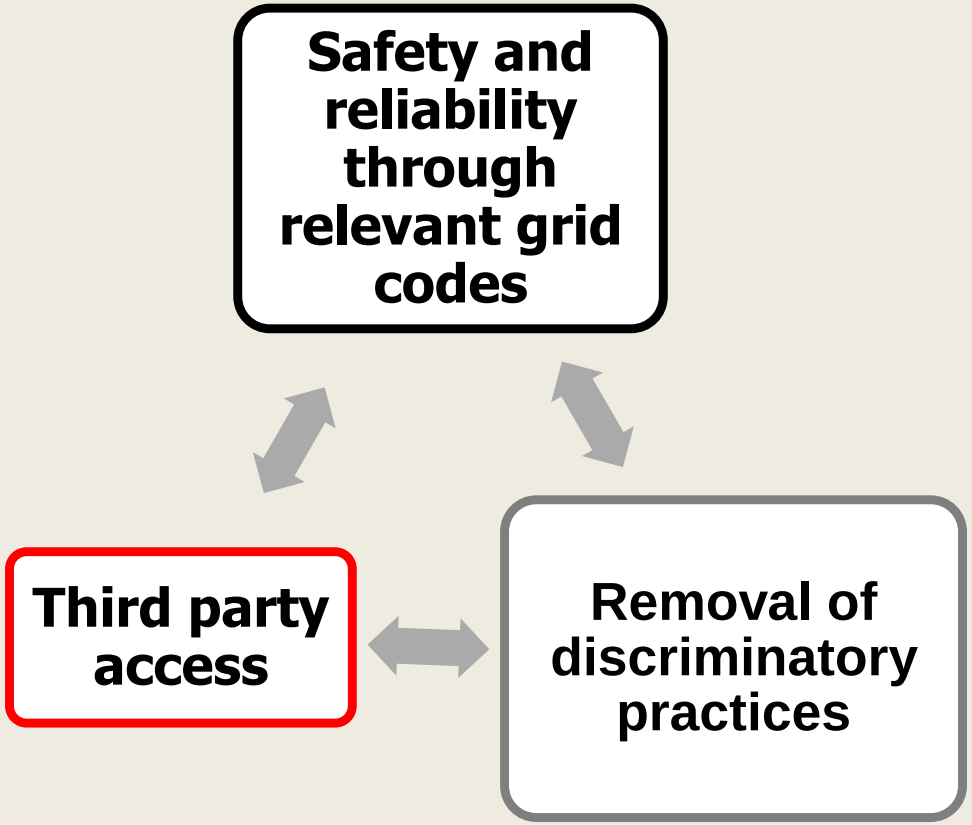
Analysis

Implementing competitive electricity markets is an immediate issue which could resolve the following:



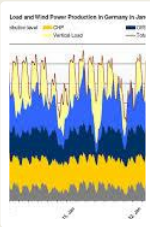
Analysis

Putting in place clear regulatory rules is an immediate issue that could resolve the following:



Analysis

Network adequacy and regional interconnection is a long term issue. Once implemented it addresses the following:



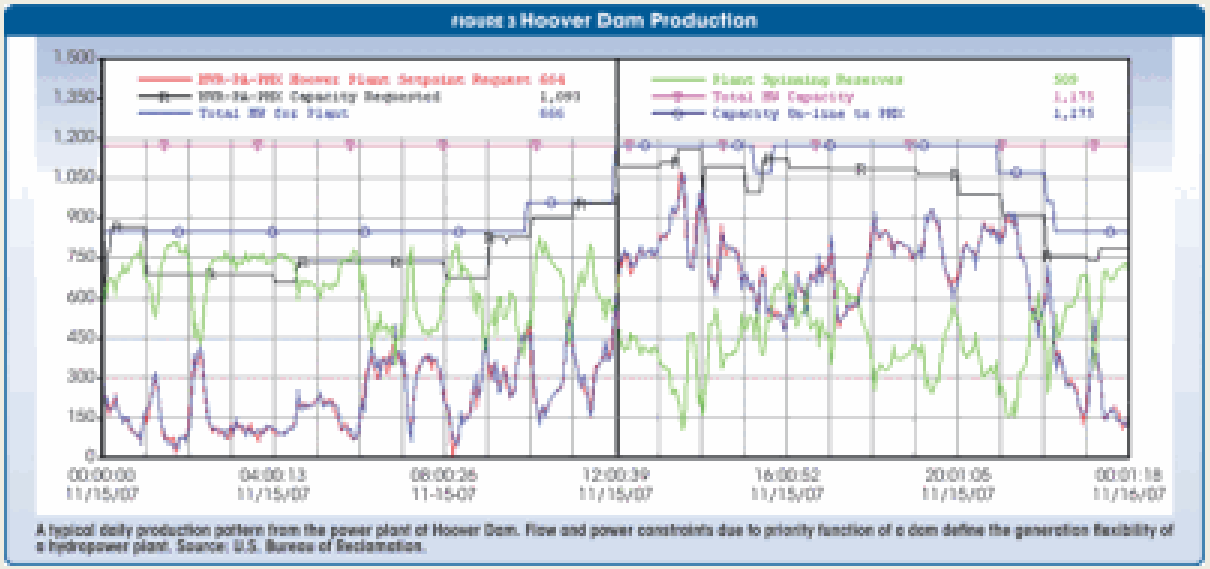
Balancing flexibility

Regional market

Effective penetration level

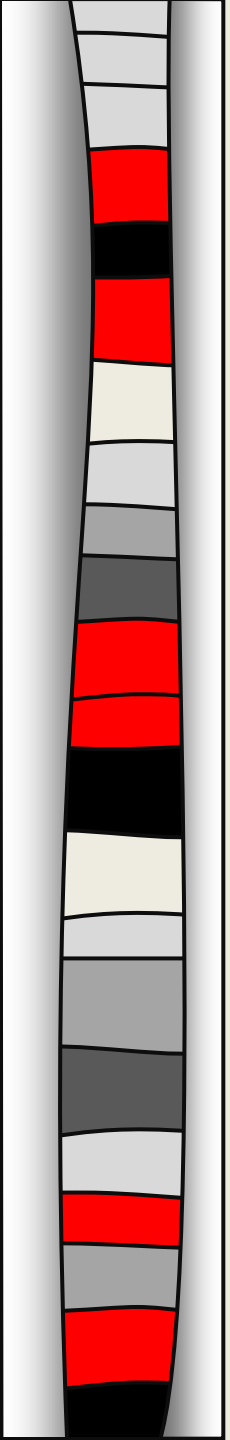
System reliability

Analysis



A typical daily production pattern from the power plant of Hoover Dam. Flow and power constraints due to priority function of a dam define the generation flexibility of a hydropower plant. Source: U.S. Bureau of Reclamation.

Better forecasting tools is an immediate issue which addresses Balancing errors and associated costs;

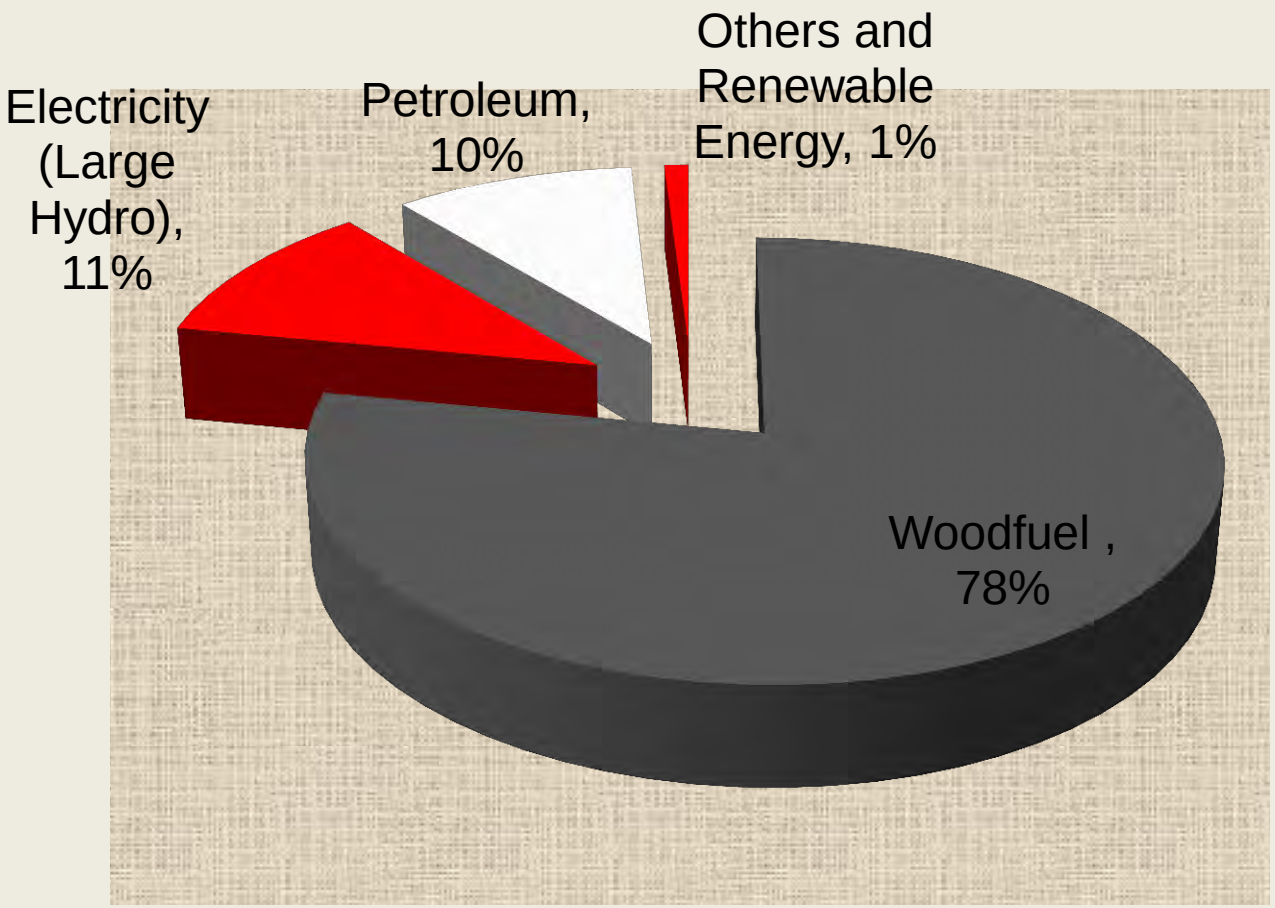


Analysis

The power market environment that, therefore, encourages large scale integration of VRE should have the following as benchmarks

- Existence of a balancing market;
- Market rules to ensure transparency;
- Priority dispatch of VRE and access to the grid;
- Requisite transmission and distribution infrastructure;
- Improved forecasting and operation routines for System Operator.

Integration Issues in Zambia- National Energy Mix



Integration Issues in Zambia- Variable Renewable Energy Resource Base

- **Solar:**
  - 6-8 sunshine Hours/day
  - Potential Energy Output of 5.5kwh/m2/day
- **Wind:**
  - Average of 2.5m/s.
  - In a few highlands and plains 5m/s
  - Need for quantification

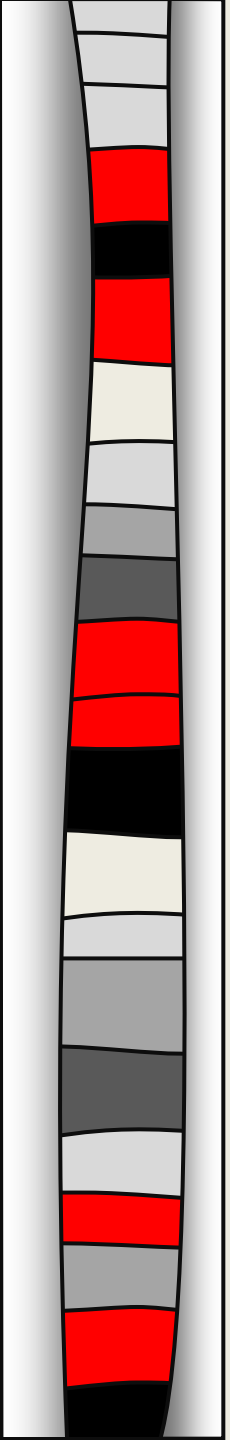
Integration Issues in Zambia- Variable Renewable Energy Resource Base

- **Small, Mini and Micro-Hydro:**
  - Extensive in northern part of the Country
  - Need for quantification

- **Geothermal:**
  - Requires quantification.

Integration Issues in Zambia

- **Current Situation:**
  - High rate of Economic Growth requires quick power generation interventions
  - No/low penetration of VRE in Zambia (less than 1% of energy mix)
  - Absence of a clear REFIT policy a barrier to investment in VRE
  - Long absence of Grid Code and open access regime was barrier to RE investment



Integration Issues in Zambia

- **Intervention Measures:**
  - Government carrying out detailed RE resource assessment
  - Introduction of Grid Code by the Regulator to guide connection of IPPs to National Grid
  - Govt. with USAID technical assistance developing REFIT Policy
  - The Regulator with USAID technical assistance developing REFIT framework
  - Government has embarked on solar projects to improve voltage profile along outlying areas of Grid
  - Govt. investing in upgrade of National Grid

Conclusion/ Recommendations

- The new Zambian REFIT Policy is key to enable market redesign and regulatory reform
- Upgrade of the existing power systems in Zambia is necessary to accommodate increased penetrations levels of VRE.
- Zambia requires detailed quantification of its Renewable Energy Resource.
- There is room for Technical assistance in implementation of the Grid Code relative to mandate of the Independent System Operator

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