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UKRAINE
NATIONAL ELECTRICITY REGULATORY COMMISSION
ANCILLARY SERVICES IN THE ENERGOMARKET

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This report makes extensive use of the material presented in a previous report by Boris Shapiro of Hagler Bailly Kiev on Ancillary Services [Ref 1] Additional references used for development of this report are listed at the end of this report

EXECUTIVE SUMMARY

This report describes procurement and compensation for Ancillary Services in the Energomarket of Ukraine It was prepared under USAID Contract No CCN-Q-18-93-00152-00 DO 18 Statement of Work I B (6)

Ancillary Services (also called System Support Services) are necessary for safe secure and reliable operation of electric power systems Ancillary Services include provision of frequency control, reactive power compensation and voltage control, and supply of various types of reserves To ensure reliable availability of Ancillary Services, system reliability and security requirements should be established first, and the rules and procedures be developed for proper identification, least-cost procurement, measurement, and compensation of such services

This report reviews various types of Ancillary Services required for the reliable and efficient operation of electric power systems Ancillary Services can be grouped into three general system support functions

- Reactive Power/Voltage Control
- Frequency Control/Load Following
- Operating Reserves

Description of pricing and compensation applied to each type of Ancillary Services are described in the following chapters This report also provides a description of the Ancillary Services utilized in the Integrated Power System (IPS) of Ukraine, and how they differ from examples of other countries

The last chapter provides a set of recommendations for formulating the requirements for Ancillary Services in the Energomarket, and discusses methodologies for pricing and procurement of such services It also recommends establishment of an Energomarket Reliability Council, which would be responsible for definition of the Operating Reserve Requirements for the Energomarket and establish the System Support Functions

CHAPTER 1
INTRODUCTION

1.1 OBJECTIVE OF THIS REPORT

1 1 1 Reliable and stable operation of the electric power system is only possible through provision of Ancillary Services by generation, transmission, distribution, and system control entities Ancillary services include frequency control, reactive power, spinning reserve, stand-by reserve, fast start, black start, and other similar services required to maintain system reliability stability, and quality of service, and enable proper and adequate response in times of system contingencies Similar services are utilized in Ukraine and countries of the Former Soviet Union under different names

1 1 2 In former times, the shear size of the system, high level of integration, and substantial size of interregional power flow, resulted in the robust and reliable operation of the system The multitude of time zones, meant availability of interregional reserves Separation of the Integrated Power System (IPS) of the Former Soviet Union into its many parts has contributed to exacerbation of problems of the regional systems Improvements in the system reliability and security would not only contribute to the quality of service in a regional level, it will also help meet the system standards required for connectivity with European grids

1 1 3 It is recommended that this report be submitted for review to the experts in Energomarket Technical Committee The proposed permanent Energomarket Technical Committees would operate under the direction of the Energomarket Board Energomarket Technical Committees, composed of experts and policy advisors from Energomarket Members, are proposed to engage in systematic evaluation, revision, and addition of Energomarket Rules Numbering system in this report is designed to facilitate discussion in expert groups

1.2 CONTENTS OF THE REPORT

1 2 1 Present procedures for implementation of Ancillary Services in Ukraine are implicit and carry-overs from the pre-independence system Addressing standards, requirements, and implementation of Ancillary Services, should be an important feature of restructuring activities

in the electric power sector of Ukraine As the Energomarket of Ukraine is developed more fully, it will be essential to provide for explicit provisions for procurement and implementation of Ancillary Services in Ukraine

1 2 2 A fully successful development of rules and procedures for provision of and compensation for Ancillary Services would require participation of experts from all realms of the industry, including NDC, and generation, transmission, and distribution companies Best forum for development of Ancillary Services rules and procedures would be the proposed Energomarket Technical Committees composed of the experts from all interested parties Material and recommendations in the report are presented for stimulating discussion among the Ukrainian experts in the Energomarket Technical Committee, based on whose recommendations the Energomarket Board would provide the final proposal for approval of the Energomarket Members The National Electricity Regulatory Commission of Ukraine (NERC) under the terms of EMA and the Energomarket Licenses will review the Energomarket Board's proposal for provision and pricing of Ancillary Services

1 2 3 Rules and procedures governing ancillary services in the Energomarket should cover the following

- Requirements for different classes of ancillary services
- Specifications for providers of ancillary services, and obligation of different market entities including the transmission company and service providers
- Methodology for costing out and appropriate compensation for ancillary services and related capital investments, including investigation of feasibility for creation of a "market" for ancillary services
- Methodology for recovery of ancillary costs from Market Customers

1 2 4 In summary, this report

- Provides a short overview of the types of Ancillary Services required to ensure reliable operation of the Energomarket and the integrated power system of Ukraine
- Reviews different procurement and payment methodologies used for pricing and compensation for Ancillary Services, practiced in different markets

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- Presents a recommendation for pricing and payment methodology to be employed in the Energomarket

1.3 KEY TERMS

Ancillary Services Terminology

Area Control Error (ACE)
Automatic Generation Control (AGC)
Contingency Analysis
Contingency Planning Requirements
Control Area
Frequency Control
Governor
Load Following
Operating Reserves
Operating Reserve Requirements
Reactive Compensators
Reactive Power
Regional Reliability Councils
Reserve Margin
Security Control Implementation
Spinning Reserves
System Security Functions SPE "Security means avoiding major disruptions"
VAr Compensators
US National Electric Reliability Council (NERC)
Voltage Control

Other Terms

The Agreement	Energomarket Members' Agreement
Genco	Generation Company
IES	Independent Electricity Supplier
LEC	Local Electric Company (Distribution/Regulated Electricity Supplier)
Minenergo	Ministry of Fuel and Energy
NDC	National Dispatch Center

NERC	National Energy Regulatory Commission
Oblenergo	same as LEC
RDC	Regional Dispatch Center

CHAPTER 2
DEFINITION OF ANCILLARY SERVICES

2.1 LIST OF ANCILLARY SERVICES

2 1 1 Ancillary Services refer to various technical services and system support functions that are necessary for safe and reliable operation of the electric power system Although the term "Ancillary" implies that these system support functions are of "secondary" in relation to the "primary" services of provision of electric energy, without Ancillary Services, no electric power system can function properly Another proper term, and commonly used in place of Ancillarv Services is the "System Support Services", which reflects the supporting nature of such services

2 1 2 As the references from Australia (Victoria), Canada (Alberta), USA (New England), listed in this report indicate, Ancillary Services in terms of type and significance are defined differently depending on the particular characteristics and requirements of each for each electric power sector [Ref 2 to 6] For consistency, this report retains the terminology and definitions listed in the previous Hagler Bailly Kiev report on Ancillary Services [Ref 1] Any reference to terminology used in other countries will be clear from the context

2 1 3 Irrespective of how different electric power systems refer to or pay for Ancillary Services each have in place rules and procedures to deal properly with contingency situations arising from loss of load or power, momentary imbalance in supply and demand, or expected future changes Ancillary Services are provided by generation, transmission, distribution, and system control entities in the electric power sector The type and quantity of Ancillary Services for an electric power system depend on the reliability criteria and operating standards adopted by that system

2 1 4 In general, Ancillary Services can be grouped into three categories

- Voltage Control/Reactive Power
- Frequency Control/Load Following
- Operating Reserves

Voltage Control/Reactive Power

Utilization of generation and other reactive compensation devices to inject or absorb reactive power in order to maintain voltage levels on transmission lines within the acceptable range

Frequency Control/Load Following Services

Application of Automatic Generation Control (AGC) and utilization of on-line generation equipped with governors to respond to momentary fluctuations in customer load In Ukraine, this service is provided by designated hydroelectric units which respond to instantaneous fluctuations in load

Operating Reserves

Utilization of spinning and fast and slow non-spinning reserve, based on Operating Reserve Requirements to provide safe, secure, and reliable operation of the electric power system

2.2 REACTIVE POWER

2 2 1 In a three-phase AC load flows, the equation describing power as product of voltage and current produces two terms One is the "real" power, which has a non-zero time-average In fact it is constant in time The other is the "reactive" power, which although non-zero in each instant, it has a zero time-average Because it is has zero time-average, it is not useful power for consumption by end-use devices However, reactive power flows affect both real line losses and voltage magnitudes, and hence, it affects the value of real power

2 2 2 Reactive power injection and absorption is required to minimize line losses and to maintain acceptable voltage levels Reactive support is provided by a combination of generator reactive power production capability, and at various points on the network, by other reactive compensation devices, including conventional shunt reactors, static VAr Compensators, tap changing transformers, switchable capacitors, synchronous condensers, and so on Most of these operate automatically to keep the voltage magnitudes near pre-specified set points

2 2 3 Remote and long distance supply of reactive power by generators is not viewed as technically and economically a suitable choice to meet local needs, mostly due to its impact on

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line losses and voltage magnitudes Furthermore, requiring generators to have reactive power available forces the generating units to operate below the levels required by optimal economic dispatch, thus imposing additional costs on generators The best options are installation of reactive compensation devices by the transmission supplier on the network as needed Local reactive power injection supports maintenance of acceptable voltage profile along the transmission lines

2 2 4 Reactive power compensation is also by customers at the customer load bus Due to reactive losses within the transformer, reactive power compensation is more effective at the low-voltage side of the transformer In the USA, retail tariffs for industrial customers reflect the impact of the customer load on reactive power and therefore, provide an economic incentive (in the form of penalties) for industrial customers to install reactive power compensation devices at their sites Rules and procedures should assign responsibility for reactive power compensation to all the entities of the Energomarket including generation, transmission, distribution, and direct access industrial customers

2.3 FREQUENCY CONTROL

2 3 1 Frequency control of the electric power system is required to maintain system efficiency, and to provide reliable and stable operation of the system System frequency should generally be kept within an acceptable range of the designated nominal frequency (60 Hz in the USA and 50 Hz in Ukraine) Frequency deviations in the system are indication of either instantaneous over-supply or under-supply of electric power with respect to system load

2 3 2 Automatic Generation Control is the principal means of Frequency Control (AGC) in the USA [Ref 7 & 8] Thermal generators equipped with AGC devices provide frequency control by adjusting their generation output to compensate for the mismatch between momentary supply and demand, and prevent unacceptable frequency deviations In some instances, such generator output changes may be accomplished through manual control involving direct operator action

2 3 3 Frequency control can also provided by *load following* provided by some hydro power plants, which due to their inherent design characteristics can provide fast response to momentary changed in load This is the principal manner of frequency control in Ukraine and Russia To our knowledge there are no generation units in Ukraine equipped with AGC

2 3 4 The concept of Control Area is relevant to the problem of Frequency Control A Control Area is part of the interconnected system in USA where all generation and load are the control of

one central control center For instance there are 100 such Control Areas in the Eastern interconnected system of the USA Implementation of AGC is usually accomplished bv the area control center Application of AGC in the USA has three general functions

- To maintain system frequency within a specified range (60 Hz in USA 50 Hz in Ukraine)
- To maintain scheduled value of interchange between adjacent Control Areas
- To maintain the generation levels at each generating unit at its most economic value

2 3 5 AGC accomplishes all three tasks indicated above through measurements of frequency deviations in the control area and through computation of Area Control Error which are based on measurements of within each area, given the schedule of net interchange AGC is also used to keep time integral of frequency in 24 hours within an exact target Hence, although electric clocks in the USA may run a bit fast in the morning and a bit slow at night but they give the correct time after 24 hours

2 3 6 Another means of frequency control is utilization of Automatic Load Shedding where strategically located relay devices respond to frequency drops in the system to cut of excess load

2 3 7 The tight frequency control in the USA (+/- 02 Hz range) is mostly due to requirements for control of scheduled interchange power flows on inter-ties A frequency mismatch between two adjacent regions results in flow of power from higher frequency region to the lower frequency region Frequency control in other counties is based on less stringent rules However AC interconnection between adjacent electric power systems such as two neighboring countries requires tight frequency control

2.4 OPERATING RESERVES

2 4 1 Reliable and secure operations of the electric power system requires short-term and long-term availability of Operating Reserves to respond to respond to sudden or expected large changes in load or during major system contingencies resulting from forced outage of generation units or transmission lines Operating Reserves Requirements are determined by planning studies, consisting of Contingency Analysis and development of System Security Functions,

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meant to prevent blackouts and major frequency and flow deviations and to provide System Security Functions

2 4 2 Types of Operating Reserves vary depending on the required time frame for their utilization In the shortest time frame, Spinning Reserves by generating units provide additional synchronized operable capacity capable of coming on line in a short period of time (seconds to 10 minutes) to satisfy sudden increases in load Spinning Reserve refers to the additional available capacity of generating units, which are actually on-line and in operation below their maximum generation loading point For longer time frames, other non-spinning and scheduled reserves in the form of 30-Minute to 60-Minute Operating Reserves can be brought on line within the specified designated time of a major contingency Other equivalent terms are Cold Start or Black Start capability

2 4 3 Other non-synchronized fast start reserves include fast-start gas turbines, pumped storage hydro generation, and available regular hydro generation capacity Operating reserve requirements can be supplied also by customers, subject to technically feasibility For instance, interruptible load under Voluntary Demand Curtailment can also be considered part of Operating Reserve portfolio [Ref 12]

2 4 4 In the USA, rules for allocating operating reserves to the individual units are usually set by the Regional Reliability Councils For instance, the rules may require that spinning reserves should account for a certain percentage of peak demand, and be capable to replace the loss of load of the largest unit The rules may also specify allocation of other types of operating reserves Distribution of operating reserves within the electrical network is also an important factor, in order to prevent "bottling" or reserves in one region, and to allow for operating of smaller part of the network as "islands" in the event they become disconnected from the larger network

2 4 5 In many cases, various types of Ancillary Services are closely connected For instance, a portion of spinning reserve, called Regulation Reserve can be used for frequency control In certain tight systems such as New Zealand, major frequency deviations may occur due to major contingencies, and these are managed through the use of spinning reserves and limited load shedding In fact, management of spinning reserve, to maintain frequency excursions within acceptable limits at minimum total generation cost, constitutes a significant part of the generation and scheduling dispatch function [Ref 9]

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CHAPTER 3
ANCILLARY SERVICES IN UKRAINE

3.1 APPLICATION OF ANCILLARY SERVICES IN UKRAINE

3 1 1 In terms of organization and operations Integrated Power System (IPS) of Ukraine was and integral part of the IPS of Former Soviet Union System support services have been an integral part of the operation of the IPS Historically, scheduling and control provided for maintaining required levels of cold and hot operating reserves to meet variation between scheduled and actual demand Momentary changes in load were met through load following services provided by designated hydro generation units Reactive power flows were adjusted in order to maintain acceptable voltage levels in transmission

3 1 2 During former times, the higher level of connectivity and shear size of the system compared to the electric power systems of USA, provided adequate protection support and reserve for reliable and secure operation of the system Separation of the power sector of Ukraine from the IPS of FSB has resulted in deterioration of reliability and security levels once enjoyed The side effects of the economic transition manifested in the form of nonpayment problem and low level of cash collections and resulting chronic fuel shortages, in addition to a host of other issues, have exacerbated the reliability and security problems

3 1 3 Provision of System Support Services in the FSU were based on a central command and control system, where system support requirements were determined by the central or regional dispatch, and schedules were submitted to generation, transmission, and distribution entities The operation of the system was based on meeting certain levels of objectives and production quotas subject to meeting the planned energy and capacity balance Economic principles of central planning, instead of market dictates, were the driving ideology behind the planning and operation of the system In that context, system support services were provided based on the command of the dispatch to meet strict reliability objectives with minimal consideration of economic efficiency and proper compensation to service providers

3 1 4 Great strides have been made in restructuring of the Ukraine electric power sector Establishment of the Energomarket of Ukraine and creation of the Energomarket Members' Agreement (EMA) and Energomarket Rules (Market Rules) have provided the basic framework

for proper functioning of the primary functions of the electric power sector of Ukraine Most of the present shortcomings of the market operations can be traced to external factors such as the nonpayment problem and low cash collections, which are generally attributable to the problems of the transition economy and lack of proper administrative and legalistic infrastructure in Ukraine

3 1 5 In the context of market reform, Ancillary Services have been considered as being secondary in nature, and for lack of any alternative, historical methods and pre market rules and procedures still govern provision of Ancillary Services in Ukraine Part of this lack of attention can be attributed to the nascent nature of the Energomarket The following points consider the present status of the Ancillary Services in the current structure of the Energomarket

3 16 Section 1 1 of the EMA defines Ancillary Services as "Services comprising reactive power, frequency control, black start, fast start, stand-by reserve and other such services required to control system stability" However, no descriptions or references are provided for the terms comprising Ancillary Services in other parts of EMA

3 1 7 Section 3 4 1 of the EMA provides the only reference to Ancillary Services It states that " ESE (Energomarket State Enterprise) will be responsible for the purchase of Ancillary Services pursuant to the Market Rules At this stage in the development of the Energomarket ESE is represented by the National Dispatch Center (NDC) for coordination and implementation of Ancillary Services The Schedule 2 of the EMA, which covers the Market Rules, does not directly refer to Ancillary Services

3 1 8 Market Rules provide indirect and partial compensation for some aspects of Ancillary Services For instance, Market Rules provide for compensation for generation which are Constrained On or Off due to system requirements, although Constrained On and Off Payments have not been implemented yet Market Rules also specify that blocks can bid prices for start-up costs reflecting the Hot, Warm, and Cold status of the generation blocks However, it is not clear whether this information is utilized in practice

3 1 9 Therefore, the EMA and its Market Rules do not provide any procedures and rules for determination of requirements for various categories of reserve, voltage and frequency control, reactive power, and other ancillary services

3 1 10 Although not clearly defined in the EMA and its Market Rules, the electric power sector in Ukraine utilizes a number of Ancillary Services to meet its requirements for a safe, secure, and reliable operations Current application of such services are based on the established rules and

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procedures inherited from the Soviet times Ancillary Service functions are performed by generation, transmission, and distribution entities in response to command of the NDC

3 1 11 Providers of Ancillary Services in Ukraine incur direct and indirect costs There are opportunity costs foregone by generation blocks which provide Ancillary Services instead of providing their primary product which is electric energy However no formal system of payment is place to compensate for the direct or indirect costs of Ancillary Service Providers

3 2 REACTIVE POWER/VOLTAGE CONTROL IN UKRAINE

3 2 1 The principal providers of reactive power in Ukraine are generators which follow instructions from NDC without proper compensation Although best approach for dealing with reactive power is local compensation, adequate supply of static compensation does not exist in Ukraine NDC requires generating blocks to have reactive power available to mitigate the deficit of reactive power in transmission lines In other electric power systems, injection and absorption of reactive power are also provided locally on the transmission lines through static compensation equipment It has been determined that long distance compensation for reactive power is not efficient in technical and economic terms

3 2 2 Generation units produce both real and reactive power To have reactive power available generation units may have to operate below their optimal load level In terms of operations in the Energomarket, voltage control may require that some scheduled generation (in-merit generation) may have to operate at levels different from the day-ahead Generation Schedule determined by the SSA In other words, some generation blocks are routinely Constrained Off or Constrained On below and above their day-ahead Generation Schedule level Limiting MW or real power output of generation blocks by NDC, especially during peak periods, results in an opportunity cost for constrained generation blocks in terms of expected revenues from potential electricity sales

3 2 3 Market rules allow for recovery of these opportunity costs in the form of Constrained Off Payments Implementation of these procedures requires continuous record keeping in a Dispatch Journal (also commonly referred as Dispatch Log) NDC has yet to develop a transparent and accessible Dispatch Journal, and make it available to the Energomarket Board, Energomarket Members, and the Settlements System Administration (SSA) for calculation of payments to Constrained On and Constrained Off generating blocks

3 3 FREQUENCY CONTROL/LOAD FOLLOWING IN UKRAINE

3 3 1 Presently there are no power plants equipped with AGC in Ukraine to match instantaneous fluctuations in load Load Following and Frequency Control in Ukraine is primarily provided by designated hydro power plants under the control of NDC which are capable of responding quickly to load fluctuations However, there are substantial frequency deviations from the design value of 50 Hz in Ukraine, principally because supply and demand balances are coordinated through the dispatchers and manual control of generation

3 3 2 Other problems contribute to significant deviations during peak and off-peak hours For instance, peak demand is likely not to be met by adequate generation due to lack of fuel resulting in frequency falling down as low as 49 2 Hz During night times nuclear and must-run units cause excess supply and forcing frequency to as high as 50 5 Hz Furthermore in contrast to the USA where average frequency in a 24-hour period is kept at a fixed level, no attempt is made in Ukraine to keep control the average frequency in a 24-hour period at a fixed level

3 3 3 A principal distinction between the approaches to frequency control in Ukraine and USA is concept of Control Areas in the USA Geographically, transmission networks in areas are divided into three major zones Eastern, Western, and Texas, whit weak connections between the three Each zone is further divided into subgroups with common reliability standards Each of these reliability areas are further divided into individual Control Areas, with the central dispatch in each Control Area responsible for control of frequency and energy and load balance within its designated area The adjacent Control Areas keep track on inter-area flow of electric power and such flows are strictly controlled to match scheduled plans Any mismatch between scheduled and actual flows are measured and reported as Control Area Error Indicator Based on deviations of Control Area Error Indicator in an area, the dispatcher adjusts generation levels in its designated area to keep the Control Areas Error to zero and at the same time keep the frequency range within the acceptable range Any mismatch between frequencies of two adjacent Control Areas, results in flow of electric power from one area to the other

3 3 4 In contrast, all geographic territories of Ukraine can be viewed as one Control Area, without the requisite AGC control required to fine tune area frequency and micromanage the inter-country power flows The interconnections within Ukraine are stronger than the regional inter-ties in USA, and there is no inherent need for maintaining balance between generation and load in different regions However, maintenance of frequency control can be achieved by division of the IPS of Ukraine into regional Control Areas, each with its own Regional Dispatch Center (RDC), and equipped AGC devices on strategically placed generation

3 3 5 Current Market Rules do not provide for compensation for provision of frequency control The designated hydro power plants provide the service under instruction from NDC A tighter frequency control can be accomplished by implementation of AGC on thermal power plants However, installation of AGC may require major refurbishment of thermal plants which are inflexible by design In fact, design inflexibility contributes to increase in frequency levels at nighttime when must run nuclear and thermal plants cause increase in frequency levels by overshooting the desired generation level sufficient to meet the nighttime load

3 3 6 Some of the inflexibility, causing overshoot in nighttime frequency, is economic in origin, and can be traced to chronic fuel shortages Some of these problems can be mitigated by addressing the problems of fuel shortages and low cash collections (a principal source of fuel shortages), and improvement in Market Rules for proper compensation for start-up and shot-down costs of generation blocks

3 3 7 In addition to desirability of maintaining frequency levels within acceptable ranges for obvious economic efficiency reasons, including prevention of damage to generation and end-use equipment, frequency control is also requirement for AC connectivity with other networks AC connection to the networks of adjacent countries requires uniform reliability and stability standards among the interconnected systems, with strict implementation of rules and procedures to enable Control Area frequency control and inter-country power flows

3.4 OPERATING RESERVES IN UKRAINE

3 4 1 The basic approach for calculation of the required level of Operating Reserves in Ukraine is the annual determination of balance of energy and capacity based on the requirements of the annual peak day The methodology was developed during the Soviet times to take advantage of the power transfer capabilities of the IPS and differences in peak hours of regions located in different time zones (Former Soviet Union covered 8 time zones) The inter-regional reserve capability coupled load following based on designated hydro power plants, provided a tight system of reliability maintenance

3 4 2 The current methodologies for establishment of reliability criteria and setting of operating reserve levels in Ukraine for shorter time horizons than annual are not based on probabilistic techniques employed in the USA and other countries Lack of established methodology coupled with lack of historical hourly data on generation, usage, and forced outages, makes it next to impossible to assign values to Loss of Load Probabilities (LOLL) for future hours or even for periods of longer time horizon in Ukraine

3 4 3 Another particular feature of the system in Ukraine is widespread application of Automatic Load Shedding (Involuntary Demand Curtailment), which contributes to the difficulty of comparing various aspects of the electric power system of Ukraine with that of USA and other countries Due to the importance of the impact of Automatic Load Shedding for the reliability of the overall electric power sector, we list other problems associated with Automatic Load Shedding include

- Historical application of Automatic Load Shedding has also contributed to the leveling of demand in FSB and Ukraine, contributed to the general tendency to design thermal power plants to operate as base-load with little or no inherent flexibility

- Distorting of data required for evaluation of Value of Unserved Energy (Value of Loss of Load or VOLL), since Automatic Load Shedding does not permit for proper valuation by individual customers of trade-off of load versus service However, it must be noted that Automatic Load Shedding is based on a priority list maintained by NDC in terms of importance of region or industry

- Making it difficult to evaluate Loss of Load Probability (LOLP) for future hours or for periods of longer time horizons Automatic Load Shedding automatically translates into LOLP of 1, and violation of reliability criteria viewed as acceptable in the USA (where some regional electric power systems are designed to experience loss of load once in 10 years)

- Application of Automatic Load Shedding also results in distortion of proper price signals in Ukraine It is not clear whether day-ahead forecast demand in Ukraine takes account of involuntary curtailments Forecast demand is one of the variables, which determines the Availability Prices in Ukraine

It should also be noted that in view of the current excess of installed capacity, the current widespread application of Automatic Load Shedding is mostly due to lower available capacity caused by low cash collections and resulting fuel shortages

3 4 4 Based on information gathered in interviews, provisions for various categories of reserve by Gencos are done under instructions of NDC, although EMA and its Market Rules do not specify different categories of reserves or state any provisions for direct compensation to generators supplying reserve We have not obtained any other official document that describes

the rules and procedures applied to establishment of the required reliability levels specification of types of required reserves, determination and setting the hourly operating reserves or forms of procurement and compensation for reserve supplies Nor is it clear how System Security is defined in Ukraine and whether there are any established rules and procedures to perform Contingency Analysis and be prepared to deal with various System Security issues Reliable operations of the IPS of Ukraine require establishment of Contingency Planning Requirements and development of procedures for Security Control Implementation

3 4 5 Market Rules allow for Availability Payments for Unscheduled Availability, which would presumably covers some of the opportunity costs of maintaining reserve capability by generation blocks The Availability Payments supposedly reflect the expected Value of Loss of Load (VOLL), and are not directly related to costs of reserve supplies The expected VOLL varies with Loss of Load Probability (LOLP), which is assumed to be a function of Operating Reserve Margin, defined as day-ahead Excess Availability (excess of Declared Availability over Forecast Demand)

3 4 6 A curious fact is that Scheduled Generation, according to Market Rules simply covers day-ahead Forecast Demand, but does not include Operating Reserve Requirements Availability Prices are determined based on the difference between day-ahead Forecast Demand and Declared Availability, and it is not clear whether day-ahead Forecast Demand also includes the Operating Reserves Furthermore, it is not clear what types of reserve would Declared Availability cover The bidding rules allow for bidding for cold, warm, and hot start therefore, the Declared Availability should cover all types of cold, warm, and hot starts

3 4 7 Additional indirect compensation is through the Constrained On and Off payments to generation blocks specified in the Section 8 3 of Schedule 2 of EMA [Ref 10] also stipulate payments for Constrained On and Constrained Off generation blocks Presumably, these payments would cover the direct or opportunity costs of generating blocks, which are either dispatched out of merit or dispatched below their scheduled generation The correspondence between the payments and type of service has not been established However, irrespective of the merits of constrained payments, current operations have not actually implemented these types of payments, mostly blamed on unavailability of a formal Dispatch Journal

3 4 8 Based on bidding rules, there are also payments for Block Start-Up costs (BSU), which would cover some of the direct costs of reserve supply if they are called for However, payments for BSU are based on bid of the block in the merit order with the highest Block Settlement Price, which is a combination of the marginal block's BSU, Block No-Load (BNL), and Block Incremental (INC) costs In other words, each block in actual operation receives the System

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Marginal Price (SMP), which partly accounts for the Start-Up and No-Load costs in some average way Market Rules do not specify direct payments for actual start-ups

CHAPTER 4
PRICING AND COMPENSATION FOR ANCILLARY SERVICES

4.1 COSTS OF SYSTEM SUPPORT SERVICES

4 1 1 According to Ref 1, a March 1996 study of costs of ancillary services for 12 US electric utilities were found to be anywhere from 0 15 to 0 68 Cents/kWh, representing 5 to 25% of the generation and transmission costs This finding underscores the underlying economics of ancillary services, and the need for proper identification of types and quantities of such services and development of rules and procedures for procurement, provision, and compensation of such services in an economically optimal manner

4 2 COSTS AND PRICING OF FREQUENCY CONTROL

4 2 1 Frequency control by generators entails direct and indirect costs In addition to the direct costs of refurbishment of the power plant and installation of equipment for AGC capability, there are indirect costs in the form opportunity costs for reserving capacity for responding to fluctuations in load

4 2 2 In addition, load following requires frequent variation in generation levels or changes in cycling modes, resulting in higher maintenance and replacement costs and reduced generation unit life due to increased wear-and-tear, thermal and mechanical stress and fatigue failure of components

4 2 3 Variation in generation level also affects unit's fuel efficiency, since it prevents the unit from operating at its designed optimal efficiency load level Hence, proper compensation for load following services should account for all categories of costs

4.3 COSTS AND PRICING OF REACTIVE POWER/VOLTAGE CONTROL

4 3 1 Reactive power and voltage control also entails direct and indirect costs Direct costs include costs of installation of equipment at all levels of generation, transmission, distribution,

and consumption for injection and absorption of reactive power For transmission operators direct costs include cost of purchase of static compensation equipment At the distribution and consumption level, local voltage control requires installation of reactive compensation devices

4 3 2 Indirect costs include opportunity costs of direct real power sale by generators which are required to provide reactive power capability by keeping their generation level at specified level instead of operating at either their optimal designed loading point or at their scheduled optimal dispatch designation

4 3 3 Since reactive energy flows affect both line losses and voltage magnitudes, marginal costs of reactive power, similar to marginal costs of real power, vary with time and location [Ref 7 (pp 116), and Ref 11] In mathematical terms, reactive power is These costs can be estimated using methodologies developed for determination of spot prices for electricity, using optimal power flow (nonlinear AC load flow) models

4 3 4 Spot prices in the form of time and location dependent prices can be introduced for purchasing and selling of both real and reactive power In addition, imposing constraints on allowable voltage magnitudes on each bus (node) on the network, it is possible to define a Transmission Quality of Supply Price, similar to Generation Quality of Supply Price (the Availability Price of the Energomarket) This price is applied when the voltage control capabilities of the network are exceeded, or when line flows threaten to exceed their thermal or dynamic limits If designed and implemented properly, the Transmission Quality of Supply Price is expected to change the network users generation and usage patterns [Ref 7 (pp 116 and 175)]

4 3 5 Cost of transport of reactive power increases with distance Consequently, the least cost and most effective options for compensating for variations in reactive power and dealing with voltage control are utilization of static compensation devices on various locations on the transmission network For this reason, in the USA, generators are not the first choice for provision of reactive power In general, due to the wide variation in time-dependent and locational marginal costs of reactive power, recovery of these costs should also reflect this time and location dependency

4 3 6 Depending on whether generation or transmission provides reactive compensation, then both generation and transmission should be able to recover the costs of corresponding types of reactive compensation provided

4.4 COSTS AND PRICING OF OPERATING RESERVE

4 4 1 Provision of Operating Reserves involves direct and indirect costs The obvious cost is availability of additional capacity beyond that used for generation, in order to meet short-term medium-term, and long-term increases in actual demand over predicted values Reserve capability is also required for responding to system contingency situations such as forced generation outages or loss of transmission lines

4 4 2 A generating unit supplying reserve incurs start-up and shutdown costs for making reserves available, even if it does not actually operate and generate electricity In addition supplying reserves means that the additional capacity is not used for actual generation of electricity, resulting in opportunity costs associated with potential loss of revenue from lost power sales A generator called upon to actually provide its spinning reserve for security control reasons will incur additional fuel and maintenance costs

4 4 3 The US National Electric Reliability Council (NERC), and its associated Regional Reliability Councils, which consist of member utilities establish reliability standards in the USA Historically, each integrated utility in the USA has been responsible for providing its own share of operating reserves to meet its "obligations to serve" as a local monopoly provider of electricity

4 4 4 Same individual responsibility also exists for utilities participating in voluntary regional Power Pools Traditionally, power pools assign individual capability requirements on their membership, and are penalized if they fall short of their assign capabilities, and therefore increase the burden on the other utilities in the pool In essence, free loaders were and are penalized A utility could provide its own reserves internally, purchase its deficit capabilities and sell its surplus capabilities Provision of capability by own means is not always the most economical choice

4 4 5 Historically, whether or not a utility in the USA operated within or outside a power pool, its costs of service including keeping adequate reserves were compensated through regulated tariffs approved by state utility commissions

4 4 6 The current restructuring effort underway in the USA, is breaking the old traditions through the deregulation of the electricity market Among new features are provisions for creation of markets for reserve There are different approaches adopted by different Power Pools in the USA

4 4 7 Typically, market members should be responsible for supplying sufficient operating reserves required for contingency planning and control implementation Operating reserve requirements of a larger generator are greater than smaller generators

4 4 8 Theoretically, it is possible to define time and location electricity spot prices applied to providers of operating reserves which reflect system security requirements [Ref 7 pp 214-217]

4 4 9 In the newly restructured California electric power sector, the California Independent System Operator (CAL-ISO) is responsible for determining the requirements and procurement of Ancillary Services through bidding by the service providers The cost of Ancillary Services are recovered from buyers in the market

4 4 10 In the newly restructured New England electric power sector, each market member is responsible for its share of operating reserve requirements Assignment of these requirements creates an obligation on each market member to provide its share of operating reserve requirements Market members are obligated to provide any surplus reserves (of various categories) to the wholesale market

4 4 11 To satisfy the requirements of the market each market member can provide the necessary reserves from its internal sources, or through bilateral contracts with other market members, or pay the cost of additional reserve supplies purchased by the New England Independent System Operator (NE-ISO) through a bidding process

4 4 12 In New England, under proposed rules, levels of various categories of reserve requirements for each member, based on each market member's demand, are set by a Working Market Rules Committee [Ref 10] Markets are defined for Ten-Minute Spinning Reserves, Ten-Minute Non-Spinning Reserves, Thirty-Minute Operating Reserves, the Hourly Operable Capability, and the Monthly Installed Capacity Each member is free to acquire its reserve requirements Those members with surplus capability (capacity) should bid all their surplus capabilities to the market Consequently, only the customers with deficit reserves are liable for reserve market payments It should be noted that the longest time horizon for capacity payments is one month

4 4 13 In essence, creating obligations on market members by NEPOOL/NE-ISO to satisfy a required level of operating reserves creates "demand" which can interact with "supply" in the market to set Market Clearing Prices for operating reserves A full embodiment of such a market can be manifested through the creation of an Ancillary Services Exchange or Auction, where

both sellers and buyers would make price and quantity bids and the market price would be established based on the clearing price

4 4 14 Hence, the fundamental requirement for the establishment of a true market in Ancillary Services is to create "demand" by assigning individual obligations Demand can be satisfied either through internal resources, or through bilateral contracts or other forms of direct purchase from suppliers, or through trading in the form of Auctions or Ancillary Services Exchange Creation of demand will enable formation of secondary markets for futures and options

CHAPTER 5
RECOMMENDATIONS FOR UKRAINE

5.1 APPROACH

5 1 1 Ancillary Services (also called System Support Services) are necessary for safe secure and reliable operation of electric power systems Ancillary Services include provision of frequency control, reactive power compensation and voltage control, and supply of various types of reserves

5 1 2 To ensure reliable availability of Ancillary Services, system reliability and security requirements should be established first, and the rules and procedures be developed for proper identification, least-cost procurement, measurement, and compensation of such services

5 1 3 Presently, provision of Ancillary Services in by generators and other entities in Ukraine are obligatory under the instructions of the NDC Rules and procedures for operations are carry-overs from the old command system, without provisions for proper compensation for such services Without strict operational rules or proper economic incentives, Ancillary Service providers may seek to optimize their revenues by avoiding following instructions for provision of such services

5 1 4 Rules and procedures governing ancillary services in the Energomarket should cover the following

- Administration Establishment of organization and administrative mechanism to develop rules and procedures for provision and procurement of Ancillary Services
- Identification Requirements for different classes of ancillary services
- Obligations Specifications for providers of ancillary services, and obligation of different market entities including the transmission company and service providers

- Pricing Methodology for least cost pricing and appropriate compensation for ancillary services and related capital investments, including investigation of feasibility for creation of a "market" for ancillary services

- Cost Recovery Methodology for recovery of ancillary costs from Market Customers

5.2 IMPLEMENTATION

5 2 1 The proper forum for development of Ancillary Services rules and procedures would be the proposed Energomarket Technical Committees composed of the experts from all interested parties Material and recommendations in the report are presented for stimulating discussion among the Ukrainian experts in the Energomarket Technical Committee, which should be organized to include representatives from NDC and NERC, and technical experts from Gencos LECs and other Energomarket members

5 2 3 The recommendations of the Energomarket Technical Committee or its relevant Working Subcommittee on provision and procurement of Ancillary Services should be submitted to the Energomarket Board, which after review and the requisite approval, will implement the recommendations Appropriate procedures call for establishment of rules and procedures in the form of Amendments or Attachments to EMA and Market Rules, which would require submittal of the proposals to the Energomarket General Meeting for final approval by the aggregate of the Energomarket Members

5 2 4 The National Electricity Regulatory Commission of Ukraine (NERC), under the terms of EMA and the Energomarket Licenses shall review the Energomarket Board's proposal for provision and pricing of Ancillary Services, and ensure that pricing and compensation methodology provide for lowest economic costs while satisfying the approved reliability criteria

5 2 5 The System Reliability Criteria, and rules and procedures covering operations under system contingencies shall be established by the proper responsible Energomarket entity Hence, organization and establishment of permanent Energomarket Reliability Council, composed of the expert representatives of NDC and other Energomarket entities is of utmost importance

5 2 6 In summary, the administrative process includes the following

- Establish an Energomarket Reliability Council,

> To define and set Operating Reserve Requirements

> To perform System Contingency Analysis

> To develop System Security Functions

> To develop procedures for responding to contingency situations

> To set the required system frequency standards

> To set the required network voltage standards

- Establish a Working Subcommittee on Ancillary Services under the auspices of the Energomarket Technical Committee,

  > To identify types and quantities of Ancillary Services

  > To determine obligatory services by type, and provider under regulated pricing to be procured at least cost by the Energomarket

  > To determine voluntary services by type, and provider under market pricing to be purchased by individual Market Member (see Ref 12)

  > To develop standards and procedures for measurement of Ancillary Services

  > To develop the rules and procedures for compensations and settlements applied to Ancillary Services

  > To develop the rules and procedures for recovery of costs of Ancillary Services from Wholesale Market Buyers

- Submit the Recommendations of the Energomarket Committee to the Energomarket Board for Approval

- Submit the final proposal to the Energomarket General Meeting for approval by membership

5 2 7 The following sections present a number of recommendations to be discussed by the relevant Working Subcommittees of the Energomarket Technical Committee and the Energomarket Reliability Council

5 2 8 Based on the final decisions of the appropriate decision-making authorities indicated above, the Energomarket Rules would have to be amended to provide a formal setting for the implementation of the recommendations for Ancillary Service pricing and compensation

5.3 REACTIVE POWER/VOLTAGE CONTROL

5 3 1 The relevant Working Subcommittee of the Energomarket Technical Committee in conjunction with the Energomarket Reliability Council should carry out the following steps

- Investigate the requirements for reactive power/voltage control on a system-wide basis
- Assign reactive power requirements by region and on a local basis considering technical and economic trade-off of remote and local reactive compensation
- Specify, where possible, types of reactive power compensation and voltage control provisions which should be mandatory, subject to fair compensation, at each level of generation, transmission, distribution, and consumption
- Specify, where possible, types of reactive power compensation and voltage control provisions which can be purchased through the creation of a market for such services, at each level of generation, transmission, distribution, and consumption
- Identify the current generation, transmission, distribution, and customer providers of reactive power compensation and voltage control
- Develop the rules and procedures to be applied at each level of generation, transmission, distribution, and consumption

- Provide guidelines for procurement of reactive power compensation and voltage control supply at each level of generation, transmission, distribution and consumption

- Provide guidelines for tariffs and recovery of costs at wholesale and retail levels which provide the correct incentives for provision of reactive power and voltage control services at each level of generation, transmission distribution, and consumption

5 3 2 An important issue to be investigated is the delineation of different types of reactive compensation most suitable to Ukraine As discussed earlier, from technical and economic perspectives, most suitable options are installation of reactive compensation devices at the strategic locations on the transmission network, and also at the distribution level and industrial customer sites Hence, a combination of mandatory rules coupled with proper economic incentives at the transmission, distribution, and customer levels should be developed

5 3 3 Pricing and compensation for availability of reactive power at generation level requires evaluation of opportunity costs of generating units required to have available reactive power by not operating at their scheduled optimal dispatch level The opportunity cost calculation can be based on the (i) latest data on block operational costs, or alternatively on block bid offers, together with analysis of quarterly dispatch and settlements data to determine the expected operations of the generating unit in the absence of reactive power compensation requirements It should be noted that there are no additional fuel requirements for generation of reactive power but there is an impact on operational efficiency of the generation unit It is assumed that these impacts are minor and can be accounted for by data on bids for block incremental cost The opportunity costs of reactive power compensation supplied by generators should be recovered through the uplift component of the wholesale market prices

5 3 4 At the transmission installation of reactive compensation devices entails direct capital costs At the transmission level, investment policy should be based on least cost procurement subject to meeting the reactive power compensation requirements Capital costs, installation costs, and maintenance costs of reactive compensation equipment on the high voltage grid should be recovered by the transmission supplier through the transmission tariffs

5 3 5 Similarly, at the distribution and consumption level, installation and reactive compensation devices entails direct capital costs At the distribution level, these costs should be recovered through retail tariffs as part of the distribution charge At the customer level, retail tariffs for industrial customers should be designed with a relevant component reflecting the costs

of reactive power imposed on the distribution system Proper tariff design can provide the economic incentive for industrial customers to install reactive compensators at their sites

5.4 FREQUENCY CONTROL/LOAD FOLLOWING

5 4 1 The relevant Working Subcommittee of the Energomarket Technical Committee in conjunction with the Energomarket Reliability Council should carry out the following steps

- Investigate the requirements for frequency control in Ukraine in terms of prospects for AC connectivity to neighboring countries for export and import of electricity especially to the European grid
- Evaluate the economic impacts of relatively loose frequency control in Ukraine on power supply equipment and end-use devices
- Identify the sources of relatively loose frequency control in daytime and nighttime and draft recommendations for mitigating the external factors
- Study the technical feasibility and economic cost-benefits of introduction of AGC in Ukraine, especially with regard to trade-off in terms of reliving load following functions by the designated hydro power plants
- Identify the strategic locations and the corresponding power plants as potential candidates for installation of AGC

5 4 2 Frequency control and load following in Ukraine is currently being provided by the designated hydro power plants These power plants are not being compensated for either the wear-and-tear of load following or the opportunity costs of not operating at full load HPP generation in Ukraine is subject to bilateral contracts between the hydro generation companies and the NDC, under regulated rates approved by NERC

5 4 3 Apart from the need for revisiting the present rate structure in place for the HPP generation, a short-term solution is to evaluate the opportunity costs of load following by hydro power plants, and provide for proper compensation If alternative providers of frequency control existed in Ukraine, these hydro power plants could have been used as base-load plants Evaluation of the corresponding opportunity costs can be based on a simulation study of utilization of these hydro power plants as base-load units The evaluated opportunity costs

should then be recovered by the hydro generation companies from the Energomarket through an additional component on their regulated rates

5 4 4 In the absence of thermal generation alternatives for load following and frequency control, hydro power plants provide an obligatory service Although there is no basis for a comparison of alternative supply, it is possible to evaluate the future costs of AGC installations and control as a basis for compensation to the hydro power plants The methodology assumes that compensation for frequency control by the designated hydro power plants is based on 'avoided future AGC costs" Another alternative is to evaluate the "avoided damage costs" to the system-wide generation supply equipment and end-use devices, as a basis for compensation Each of these methodologies requires careful evaluation, and regulatory review to ensure that compensation over opportunity costs is not excessive

5 4 5 When and if AGC methodology is adopted in Ukraine, compensation for frequency control and load following services should consider opportunity costs of making the AGC service available by the AGC equipped thermal power plants An AGC generation unit will be required to maintain additional available capacity to be used as required under the AGC regime which entails opportunity costs The resulting opportunity costs can be evaluated either by simulation of system operations, or through the investigation of the block bid data by the AGC units together with analysis of the market prices for energy and availability and expected generation levels of the AGC units in absence of AGC responsibility

5 4 6 Another important component of the AGC related costs is additional depreciation and maintenance costs due to expected shorter time life and more frequent equipment failure, caused by wear-and-tear, additional mechanical and thermal stress, and fatigue failure

5 4 7 Under AGC application, AGC costs, as defined above, are to be recovered by the AGC units through an additional component in the uplift component of the wholesale prices The capital and maintenance costs experienced by the NDC (which will implement and have operational control over AGC) shall be recovered by NDC

5.5 OPERATING RESERVES

5 5 1 The relevant Working Subcommittees of the Energomarket Technical Committee in conjunction with the Energomarket Reliability Council should carry out the following steps

- To define and set Reliability Standards

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- To perform System Contingency Analysis
- To develop System Security Functions
- To develop procedures for responding to contingency situations
- To develop a probabilistic methodology for daily determination of Operating Reserve Requirements based on day-ahead forecast demand LOLP and generation unit and customer load size

5 5 2 In particular, the relevant Working Subcommittees should perform the following

- Investigate the types of Operating Reserves required, such as Spinning Reserves 10-Minute Non-Spinning reserve, 30-Minute Operating Reserves, Daily Operating Capabilities, Monthly Installed Capacity, and so on
- Identify End-Use alternatives for Operating Reserve Supply, such Interruptible Loads and Voluntary Demand Curtailments (see Ref 12)
- Determine geographic distribution of Operating Reserve Requirements to prevent "bottling" of reserves and to enable "island" operation of isolated sub-networks in case of contingencies
- Assign individual Operating Reserve Requirements and capabilities to both Wholesale Market Producers and Suppliers in terms of percentage of expected peak demand, LOLP, and generating unit and load size
- Investigate different procurement strategies, in terms of
  - Mandatory Operating Reserve provisions subject to regulated tariffs,
  - Bidding in the Energomarket by Wholesale Producers for Supply with the Energomarket acting as the Monopsony Buyer,
  - Allowing individual purchase by Wholesale Market Suppliers through bilateral contracts,

- Creation of a Market/Exchange in Ancillary Services by participation of Buyers (Demand) and Sellers (Supply)

▸ Analyze the pricing, compensation, and cost recovery under various schemes

5 5 3 The fundamental requirement for creating of a Buyer market is assignment of operating reserve capability obligations to buyers (Wholesale Suppliers and Customers) by rules developed by the Energomarket Reliability Council, reflecting expected load of each wholesale market customer and its impact on the Energomarket operating reserves

5 5 4 In its simplest form of monopsony purchase of Operating Reserves by the Energomarket supply of Operating Reserves should conform to the standards and requirements set by the Energomarket Reliability Council

5 5 5 Available capacity under each type of Operating Reserves classifications would be eligible for compensation under the pricing rules established for the corresponding type of Operating Reserve Any available capacity beyond the established requirements (which may change from hour to hour) should not be paid

5 5 6 Longer-term Capabilities covering a month, or a season, or a year and if warranted multi-year requirements (under the expectation for economic recovery and need for additional capacity in the future) can be defined by the Energomarket Reliability Council However there would be no justification for payment to "excess" Declared Availability beyond the needs specified by the Operating Reserve Requirements

5 5 7 Each type of Operating Reserves entails opportunity costs for supply the available unused but operable capacity These opportunity costs will provide the main component of compensation to providers of operating reserves

5 5 8 In the monopsony purchase scheme, the Energomarket through the NDC will assign Operating Reserve obligations to each supplier The System Settlements Administration will evaluate the opportunity costs of each individual reserve provider

5 5 9 Opportunity cost evaluations will be based on consideration of Scheduled Generation with and without operating reserve requirements, using the original price bids of each generation block and the hourly SMP and AP

5 5 10 Additional compensation is required in case the available operating reserves are called upon to meet the system contingencies These include additional costs for actual operations based on actual energy price bids of generating blocks and the system SMP and AP

5 5 11 Operating reserve costs are to be recovered through uplift Alternatively recovery can be prorated based on each wholesale market supplier obligations or load

5 5 12 Under a Bidding Scheme, each Operating Reserve Supplier will bid its price and the SSA will choose the supplier candidates through Merit Order Ranking from lowest to highest bid up to the level required to meet the operating reserve requirements

5 5 13 Under a Bilateral Purchaser scheme, each Wholesale Market Supplier will be required by the Energomarket to cover its own operating reserve obligations (assigned by the Energomarket) through individual bilateral contracts Those without certifiable coverage, would then be subject to payments for any additional operating reserves that the Energomarket would procure from suppliers

5 5 14 Under a full Ancillary Service Market/Exchange, Energomarket Producers and Energomarket Suppliers (Customers) without bilateral contracts will bid their prices at the Ancillary Services Exchange and through auction, a Market Clearing Price for different types of ancillary services will be established

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